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Sixth Annual

ARMY HUMAN FACTORS ENGINEERING CONFERENCE

3-6 OCTOBER 1960

U.S. ARMY ENGINEER RESEARCH
AND DEVELOPMENT LABORATORIES
FT. BELVOIR, VIRGINIA

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WASHINGTON 25, D. C.

CRD/J

14 December 1960

SUBJECT: Sixth Annual U. S. Army Human Factors Engineering Conference: Foreword and Transmittal

TO: See Distribution

1. This Report is the record of subject Conference held at Fort Belvoir, Virginia, 3-6 October 1960, and is published and hereby transmitted for the information and retention of the personnel and agencies indicated on the distribution list. The Conference was attended by the persons listed in Appendix I of this Report, and is annually sponsored by the Army Research Office of the Office of the Chief of Research and Development, Department of the Army.

2. This transmittal, and the continued annual sponsorship of these Conferences by the Office of the Chief of Research and Development, reaffirms the demonstrated value of the Conference and its printed Report in facilitating exchange of information among developing and using agencies and personnel concerned with the man-machine compatibility of U. S. Army materiel. The Appendices to this Report again constitute an authoritative and current compendium of the human factors engineering work programs of the U. S. Army Technical Services. As indicated in my transmittal of last year's Conference Report, these Conferences have played a vital role in bringing into full mutual awareness and coordination the diverse separate elements of the Army's human factors engineering activities.

3. This Sixth Annual Conference therefore, in response to General Trudeau's guidance of the previous year, has enlarged its scope to include other elements of the Army's Human Factors R&D program as well as related activities of civilian industry. It is anticipated that future Conferences will continue to consider and clarify this broader scope.

4. The Army's Human Factors Engineering Committee has again done a commendable job in planning and conducting a thoroughly effective Conference. The Committee deserves every encouragement and support for their continued concern to assure that Army weapons and equipments are compatible with the skills and human limitations of the soldiers who must operate and maintain them in and for battle.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

Wm. J. Ely

Wm. J. ELY
Brigadier General, GS
Director of Army Research

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ARMY, INDUSTRY, AND THE SOLDIER
REPORT OF THE
SIXTH ANNUAL ARMY HUMAN FACTORS ENGINEERING CONFERENCE (6th),

3-6 OCTOBER 1960

U. S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
FORT BELVOIR, VIRGINIA.

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ARMY, INDUSTRY, AND THE SOLDIER
Report of the
SIXTH ANNUAL U. S. ARMY HUMAN FACTORS ENGINEERING CONFERENCE

3-6 October 1960
Fort Belvoir, Virginia

CHAPTER 1. INTRODUCTION

A. BACKGROUND

References:

a. Conference Report, "Army Human Engineering Conference," The Pentagon, 14-15 December 1955.

b. Report, "Second Annual Army Engineering Psychology Conference," Army Medical Research Laboratory, Fort Knox, Kentucky, 7-9 November 1956.

c. Report, "Third Annual Army Human Factors Engineering Conference," Quartermaster Research and Engineering Command, Natick, Massachusetts, 2-4 October 1957.

d. Army Regulation 70-8, "Research and Development, Human Factors Research," 1 July 1958.

e. Report, "Fourth Annual Army Human Factors Engineering Conference," U. S. Army Chemical Center, Maryland, 9-11 September 1958.

f. Report, "Fifth Annual Army Human Factors Engineering Conference," Redstone Arsenal, Alabama, 22-24 September 1959.

Sponsorship and Planning of the Conference

The Annual U.S. Army Human Factors Engineering Conference is sponsored by the Chief of Research and Development, Department of the Army. Five such Annual Conferences have previously been held and are reported in references a, b, c, e, and f.

In accordance with referenced, planning for the Conference, as well as follow-up of its suggestions and recommendations, is accomplished by a U. S. Army Human Factors Engineering Committee. The Committee is composed of representatives of the Chief of Research and Development (Chairman), the U. S. Continental Army Command, and each of the U. S. Army Technical Services. In addition to the above representation directed by U. S. Army Regulation, the Committee has been augmented during 1960 by regular participant observers (without vote), of The Adjutant General's Office; the Human Resources Research Office (HumRRO), of George Washington University; and the Army Participation Group at the U.S. Navy Training Device Center (USNTDC).

THE Purposes of ~~the Conference are:~~ THIS REPORT are:

~~a.~~ To provide direct exchange of information on human factors engineering among personnel of U. S. Army development agencies, and between these and representatives of user agencies and other qualified individuals,

~~b.~~ To provide recommendations and suggestions to be followed up by the U. S. Army Human Factors Engineering Committee to assure exploitation of all opportunities for improving man-machine compatibility in the design of U. S. Army materiel,

~~c.~~ To provide ~~a Conference~~ Report which will serve as a useful and complete single compendium of current work programs and related information concerning all U. S. Army human factors engineering research and development activities.

The Sixth Annual Conference was called to order in Humphreys Hall, Ft. Belvoir, Virginia, at 0930 hours on Tuesday, 4 October 1960, by the General Conference Chairman, Dr. Lynn E. Baker, U. S. Army Chief Psychologist. Registration of the conferees had previously been accomplished from 1500-2300 hours on 3 October 1960 at the Charterhouse Motel, at which most of the conferees were quartered.

The invocation was pronounced by 1st Lieutenant B. R. Nix, Chaplain, Ft. Belvoir, following which the General Chairman introduced Major General Stephen R. Hanmer, Deputy Chief of Engineers for Military Operations.

B. WELCOME TO THE CONFERENCE, address by Major General Stephen R. Hanmer, Deputy Chief of Engineers for Military Operations, U.S. Department of the Army

Good morning, Dr. Baker, Mr. Morse, General Trudeau, ladies and gentlemen.

It is a distinct pleasure for me to extend to you greetings from General Itschner, the Chief of Engineers, and to take this opportunity to add my welcome to his at this opening of the Sixth Annual Human Factors Engineering Conference. A glance at your program indicates the interesting, stimulating and informative sessions which are ahead of you.

We in the Corps of Engineers are keenly aware that machines do not fight alone, we know that our machines do not plant mines, or move earth, or build bridges, alone -- behind them designing, producing and using them are men.

We have been impressed with the role that man, especially in the person of the Engineer soldier, has played in the many successes which we have enjoyed throughout the long and proud history of our Corps. We are alert, as I will point out, to his crucial importance in potential engineer operations of the future. Therefore, we are quick to assert that we must be and are vitally interested in each facet of the multiplicity of human factors which are a part of and influence our heterogeneous operations.

As an example, I note that part of our Corps' responsibility is the training of engineer troops, and consequently, we are seriously concerned with all of the intricate human factors at work in the training situation. Our Engineer School here at Fort Belvoir instructs officers and enlisted men in specialized engineer subjects and in the operation and maintenance of technical equipment. As you will see tomorrow afternoon during the demonstrations which have been planned for you, one field which has been given much attention is the development of effective methods of training. Any assistance you may offer in this area of our work is most welcome.

Within the Corps of Engineers we are also sensitive to the importance of human factors in equipment design. At previous conferences you have heard us speak of our concern with these human factors problems in connection with equipment maintenance and the problem of adequately including human factors requirements in specifications. You have heard of our efforts in relation to specific items of equipment such as the hand-held mine detector and the infrared helmet-mounted binoculars. You will hear more of our interest in and concern with human capabilities in relation to equipment design during this conference.

I am pleased to observe that the theme of your conference this year is "Army, Industry and the Soldier". It is gratifying to see that word "industry" in the theme and to know that representatives of private industry are present at this conference. I understand that this is the first of your conferences in which industry and our many consulting firms have so fully participated. This point is especially important to us in the Corps of Engineers because we count heavily on using commercial equipment as much as possible and with minimum modification.

It is enlightening and I believe allows great insight into many of our human problems if one pauses periodically to reflect on the fact that we Homo sapiens of today have changed little from our ancient ancestors. The man who swung the stone axe and the man who used the D-handled shovel were much the same, and they are also much the same as the man who operates the mammoth drag lines of today. The rapid progress of modern technology has succeeded in relieving man of much of the burden of heavy physical work, and we are well advanced in matters of remote control and the automation of complex operations. Yet as we free man of some duties, we tend to tax him with others. A prime example illustrating this point is the speed or rate with which most operations are carried out today as compared with, let us say, 50 years ago; consider the differences in speed, then and now, of autos, aircraft, earth-moving operations, or mine planting. We are asking men to react faster, to handle more information in less time, and to make more decisions more rapidly than ever before, and in general the consequences of these decisions are becoming increasingly significant. Yet as we have noted, the human component remains essentially unchanged and thus is emphasized for us the necessity of matching our complex and variable machinery to the relatively constant capacities of the human and this, of course, is your field of special interest.

One problem area which forcibly projects itself upon us and one which I would like to refer to you as a challenge centers around the variety of environments in which man, in his technological advance, seeks to survive.

One of these is the environment which could be created by Chemical, Biological and Radiological warfare. As an example, obstacles normally encountered in wartime can be contaminated to make access hazardous and time consuming, thereby enhancing the value of the obstacle. In addition, the individual may become so encumbered with protective devices that simple survival consumes most of his energy. Thus contamination in CBR warfare reduces efficiency and requires unusual efforts to overcome its effects.

Thus, the Engineer Research and Development Laboratories have developed a lead shielded cab for a bulldozer which will permit a man to operate the dozer in an area contaminated by radioactivity. But I submit to you that this operator's problems are not the same as those of a dozer operator on a peacetime road construction job.

During this past summer we have been constructing a 100-man semipermanent camp, complete with nuclear power plant, under the snow of the Greenland icecap. This camp, called Camp Century, will be occupied this winter by personnel of the Army Polar Research and Development Center. This will mark the first occasion that man has spent a winter on the icecap of

Greenland or arctic or antarctic with a nuclear reactor as the prime source of power. It has taken years to develop our capability to work in the Arctic, and we will learn much more, I am sure, about the problems of living and working there during the winter months. It is against earthbound problems such as these that we are now struggling.

The polar regions have the most hostile environment on earth, but they are warm and friendly compared to the environment on the moon. For instance, in the earth's polar regions the temperature varies annually from about plus 50° F. to minus 100° F; on the moon it varies from plus 265° F. down to minus 270° F., depending upon whether the area is in sunlight or shadow. In addition, man must contend with a nearly absolute vacuum, with solar and cosmic radiation, and with meteorite bombardment. Different from that of the earth but of potential advantage to man is the lunar gravity which is only one-sixth that on earth. Today it is accepted as a fact that man will someday leave this planet and travel to other bodies in our solar system and perhaps beyond. If this tremendous vista of the future is to be explored and exploited, man must be able to survive there. Because the moon is obviously the next way station in our exploration of space, the Engineer Research and Development Laboratories here at Fort Belvoir have studied the construction requirements for a lunar base. It has been concluded that the technical capability to move man and his materials to the lunar surface will be achieved within the lifetime of most of us here today -- indeed, by the end of this decade or shortly thereafter. But, bases on the moon cannot be built and utilized until the means of sustaining men on that satellite are worked out in detail. You human factors people have a heavy responsibility in these and other problems of the future. Are you ready to specify what is needed, and only that which is essential to sustain him? Are you prepared to assist the physicists and engineers in the design and production of systems of equipment for such operations?

These are some of the problems which confront us now and the kinds of problems which we will face in the future. I wish you a most successful conference, and I know that it will profit us all in our search for the best possible solutions to man-machine compatibility and keeping man master of himself and his weapons. The stress in this conference on a close relationship between the Army and Industry, in the Human Factors Engineering field, will redound ultimately to the great benefit of the individual soldier -- and he is still the key to success in battle.

C. ARMY, INDUSTRY, AND THE SOLDIER, keynote address by Mr. Richard S. Morse, Director of Research and Development, U.S. Department of the Army

Mr. Chairman, General Trudeau, General Hanmer, ladies and gentlemen:

It is a pleasure for me to be here at this SIXTH ANNUAL ARMY HUMAN FACTORS ENGINEERING CONFERENCE. I am gratified to note that fully a third of you here are from industrial and university research and development facilities, and also to note that the Human Resources Research Office (HumRRO), The Adjutant General's Personnel Research Branch (PRB), and the Army Participation Group at the Naval Training Device Center (NTDC) are also fully represented in this conference and on its program. As General Trudeau indicated last year, it is appropriate and necessary that all aspects of the Army's human factors R&D effort combine with the Technical Services and the Nation's university and industrial talents in coordinated team-work for man-machine compatibility.

The objective of this team-work, in a nutshell, is promptly to bring the best research to rapid development and operational use for the maximum effectiveness of the soldier.

To emphasize this necessary team-work I consider that it was highly appropriate for your planning committee and your hosts, the Engineer Research and Development Laboratories, to select as the theme and slogan of this Conference

"ARMY, INDUSTRY, AND THE SOLDIER."

With that theme in mind, I propose briefly to remind you of the nature of the situation which faces us and then review some of the trends of research and development in the U. S. and the rest of the world today which I think will be of importance to your future work.

Those of you who are already successfully engaged in exploiting all opportunities for improving man-machine compatibility in the design of Army materiel perhaps already understand the threat that we face and the way in which the Army looks at this threat in terms of its mission. You also understand increasingly, I am sure, that the design of our equipment, the training of our troops -- officers and men --, and their selection and assignment to military duties are all inter-related aspects of the problem of Army human factors research and development. We can succeed with our research and development in this area only if we are aware of these inter-relationships even when, for

convenience, we treat selection, training, and human factors engineering separately.

In the Army, we feel a sense of urgency about these matters. We feel this sense of urgency because of the threat we face.

Our sense of urgency springs from the realization that we live and work today in a period of vital importance. We are not fighting today for tailfins and a color television set, we are fighting for survival.

Forty years ago science and its application moved at what seems a leisurely pace by today's standards. Communism then was a second-rate cafeteria philosophy -- and it wore a beard.

Today, communism has seized a third of the earth, and outermost space is soon within its reach.

It took man almost three-quarters of a century to go from sail to steam in naval warships. By contrast, since 1944 atomic energy has been harnessed to drive surface and undersea vessels, fission and fusion weapons have been developed, and sophisticated guided missiles are now operational in all of our Armed Forces.

We live in an era in which change is more rapid and meaningful than in any period in history. We see in our lifetime the dramatic fading of the boundaries of empires on our globe, while at the same time outer space itself becomes touched with a national interest.

In former times the soldier's peacetime assignment was said to be merely to "keep alive the military art". Today in Europe and the Far East Army divisions are deployed. Throughout 44 countries U. S. Army personnel are engaged in the training of some 200 allied ground divisions. Another large segment of our current strength is contributing to the air defenses of our own country.

These forces are not merely "keeping alive the military art." The free World is the prime target of an all-out offensive. The Communists persistently engage us on every front and by every means which they calculate would bring them success; and their threat of direct military action is ever constant. The military threat is real, and the world is changing more rapidly than ever before in history.

In such a world of real threat and rapid change we must realize that the greater danger to the Free World lies in the rapidly growing capabilities of the Soviets in science and technology. The rate of increase of Soviet production of scientists and technologists exceeds the rate of increase in the U. S., and as of this moment they have more already than we have if you count their engineers and agricultural scientists. They are making rapid strides in the physical and life sciences; they have long had excellent capabilities in physics and mathematics; and Russia has become one of the leading nations of the world in the geophysical sciences. Russia is also among the leaders in electronics, and is displaying a vigorous interest in electronic applications to neurophysiology.

One of the outstanding strengths of Russian science today is their ability to obtain, translate, and use scientific information from all over the world. Visitors to the Soviet Union have been amazed at the completeness of their scientific libraries, and at their ability to process and abstract scientific information. It is not at all impossible that the complete translations of at least the unclassified portions of this Conference will be available in translation to interested technical personnel in the Soviet Union fully as soon as the printed Conference Report is available to you who are present here. This capability, together with the ability of the Soviet government to direct the efforts of their scientists, insures strength as well as speed in their scientific development.

The reality of the threat, the speed of change in the world, and the strength and rapidity of the Soviet technical advance -- these are the facts which give us in Army research and development our sense of urgency.

But in psychology and the social sciences we in the free world are bound by our traditions and beliefs to consider man as our most precious resource. This leads us to aspire to apply our most rigorous scientific logic and techniques in psychology and the social sciences as well as to the physics and chemistry of the world around us. To the degree that the Soviets are constrained by a state-imposed mystique they may be deprived of this power. In the field of economics, for instance, only within the past few months [Time 26 September 1960] a foremost Russian economist, Stanislav Gustavovich Strumilin, gives evidence that Soviet estimates of their industrial growth have been consistently over-stated because of a technical error which has long been suspected by economists of the Free World.

More specifically in the human factors areas of interest to this Conference, the Free World may continue to have a capability of stronger and more rapid development of a science and technology for: (1) measurement of human individual differences; (2) management of man's ability for self-modification through learning, training, and education; (3) objective prediction of human purposive performance; and (4) matching of human and machine capabilities for maximum effectiveness and productivity.

Application of such a technology in the development of Army materiel will influence,

and be influenced by, the following general tendencies increasingly observable in modern military equipments:

(1) Increasing replacement of man as a power source

(2) Increasing complexity of machines with frequent resort to automation of many routine and even some skilled tasks

(3) Shift in the requirements for manpower from operator activities to testing, make-ready and maintenance, and supply activities

(4) Increased proportion of personnel involved in communications and data processing

(5) Increased emphasis in management and decision making in larger proportions of job assignments

(6) Increased emphasis on programming and control and monitoring of machine programs

(7) Increased need for determination of those functions which are best performed by human beings and least suitable for assignment to machines.

These and other tendencies observable in modern hardware development add up in terms of human factors to: a decrease in emphasis on motor skills; an increase in emphasis on perceptual skills and intellectual abilities; an increased emphasis on human relations, leadership, and command skills; and no reduction in the demands for old-fashioned courage, loyalty, and persistence.

In U. S. Army Research and Development it is our responsibility to exploit Free World capabilities in psychology and social sciences fully in developing the weapons and equipment needed by our Army to meet the tremendous threat to our survival. Beyond this, we must also participate to a measured degree with Army "user" agencies in the development of techniques for the use of these weapons and equipments.

Our efforts must focus primarily on achieving the means for our ground forces to win on any future battlefield -- nuclear or non-nuclear, limited or general, of longer or short duration. In the simplest terms our human factors program must apply a developing technology of human behavior to assist the soldier to move, shoot, and communicate more effectively in any type of warfare against any potential enemy.

It is clear to me that we possess in the Free World all of the capacities required to achieve this in the face of the continuing threat and a continuously accelerating rate of change. We have the capacities, we must, of course, continue to increase and improve them.

Beyond this, however, we must somehow learn better to organize our resources of technological talent and our know-how. We must increasingly recruit and focus the brains of our university and industrial research and development establishments to join with our "in-house" competence for the solution of Army problems.

How this organization will finally be arranged for best exploitation of science and technology on behalf of the Free World I suppose no man can say right now. I venture to predict, however, that it will have at least the following attributes and characteristics:

1. Increased sensitivity and responsiveness to clearly identified leadership and policy guidance;

2. Substantial exertions on so-called "basic," as well as applied, science;

3. A sustained and persistently continuing effort in which generation and utilization of talents is at least as important as dollars; and

4. Greatly decreased lead time between the demonstration of the feasibility of a new concept and the delivery of a capability to the troops for operational use.

Both the underlying science and the applied technology of Army human factors engineering have been clearly demonstrated to be an increasingly necessary ingredient of the total Army research and development effort both now and for the future. I hope I have succeeded in this brief presentation in making clear to you both the urgency of our job and the broad outlines of the direction in which our future lies.

I congratulate the members of this Conference on having well carried forward the development of the relatively new human factors engineering technology in the Army. The journey ahead will be long -- it must also be swift.

Thank you.

D. THE SOLDIER FIRST, Address by Major General Louis T. Heath, Deputy Chief of Staff for Materiel Development, U.S. Continental Army Command

Mr. Chairman, gentlemen:

It is a pleasure to be here at this Annual Human Factors Engineering Conference. We of U.S. Continental Army Command are very much interested in and concerned with Human Factors Engineering.

U.S. Continental Army Command's interest in Human Factors Engineering derives from the simple fact that we in the Army are humans and our enemies are human beings. The world is peopled by humans and the conflicts which take place are conflicts between

human beings. The nations of the world are made up of human beings. Whenever nations or groups of nations clash, the conflict is by and between human beings. In order to end these clashes or conflicts human beings must be influenced. When force is used to influence a people and their leaders this becomes war. In war the ultimate persuader is the destruction of the enemy force and getting his population in a position where it can be influenced by ideas or rifle butts applied individually if need be.

Today we find the United States and its allies engaged with the communist nations in a protracted conflict. This conflict could last five to ten decades.

The aim and purpose of our national strategy in this protracted conflict must be to make sure that the United States wins and survives. Our strategy requires balance and flexibility. No other strategy can succeed in a protracted conflict where every conceivable product of human activity is brought into the struggle by our communist enemy. In this protracted conflict we face military power, the threat of military power, propaganda, subversion, treachery, economic warfare, and sociological warfare. These means are used against us by a despotic and fanatic leadership firmly mounted on the communist power apparatus in an ideological framework having no spiritual values or moral code.

To be successful in this protracted conflict we must be able to field winning armies. This is an essential part of the successful strategy to insure our survival.

Armies win when their infantry can advance and kill or capture the enemy soldiers without prohibitive losses. When the enemy's forces are destroyed we can then invade the enemy's country and dominate him.

Our armies are made up of men and the enemy, which we must dominate, is also made up of men. Thus human factors are with us every day in our task of building winning armies. To win, our armies must be able to advance their infantry by many means; these include maneuver, firepower, deceit, deception, counterfire, and logistic support of all kinds. Our armies must be able to counter the defensive efforts of the enemy by superior use of our offensive weapons. Every weapon system which he uses must be countered or interfered with in one way or another. This makes necessary counter battery efforts against his artillery, air defense against his aerial assault, and many others. If we fail to do this, then he can destroy our army and defeat it.

Modern industry and science have made necessary a wide variety of weapons in our army. These weapons are used, handled and maintained by men. The men win the battles by using the weapons. The man is the key element because it is he who has the intelligence, spirit, determination, the heart and courage to overcome adversity, privation and defeat.

In the Department of the Army organization of its job of fielding winning armies, the Commanding General of the U.S. Continental Army Command has been given the task of coordinating combat developments. Combat developments are the research, development, testing and early integration into the army of new doctrine, new organization, new materiel, to obtain the greatest combat effectiveness, using the minimum of men, money, and materiel. This brings us directly to the problem of human factors across the board as it affects organization, doctrine and materiel.

Through many centuries of history the growth of science, as it affected weapons, was very slow; also the growth of human organization was slow. Then the industrial revolution took place, it speeded up changes in weapons and materials of war very greatly. In this current century the explosive revolution in science and applied science and human organization has speeded the process of change in military equipment into a dead run, and it is in fact now tied to the tail of a rocket. These facts have brought many new potential weapons and equipments into the picture at such a great rate that special organizational measures have been taken to speed up the study and evaluation of the potential effects on the future battle field and the soldier. Combat Developments offices and elements throughout the army have been placed under the Commanding General of USCONARC to make them more effective.

Our problem now is to evaluate and estimate in advance the potentials of new weapons or weapon systems and related equipment, to determine their effect on the future battle field and on the soldier, then devise organizations, doctrine and technique for the employment of this equipment vis-a-vis our enemy and then integrate it into the structure of the army so that our army will be a winning army from the outset.

Human factors enter into this process at every turn. With each concept or item of equipment, many questions affecting human factors must be answered. How will this new tactic or concept affect training? How will this new equipment affect training? Will it increase the complexities of the training task? Can soldiers handle the equipment in the high stresses of battle?

Soldiers can be trained in many complex skills, providing time is available. However, the modern soldier requires instruction in so many areas that the training time increases greatly. There is a great need to keep the training time short because when the fighting starts we must quickly train many more soldiers. If we base our equipment on operating skills which require a year or two years to acquire, then we will be in the hole when the fighting starts.

Human factors research can aid us greatly by helping to keep weapons and equipment simple and man-compatible, and helping us to keep the training task within practical limits.

The complexities of modern equipment, which will give us literally fantastic capabilities, is a continuing problem. Careful human factors engineering in the development of this equipment can make it practical for field use. Improper human factors engineering can make the equipment unavailable in the field or delay it. Improper human factors engineering can leave us with insoluble training problems.

Human factors engineering problems of equipment range from the very simple special problem of providing enough room for the soldier in the combat vehicle to more sophisticated problems involving complex use of the senses, brain, and muscular coordination.

CONARC is working constantly with the evaluation of human factors in a wide variety of projected situations involving new organization, new doctrine and new equipment.

In regard to weapons and equipment CONARC seeks to get new equipment which will do its projected job, still possess simplicity, ruggedness, reliability and lightness, and which will not force us into insoluble training tasks.

CONARC looks to the technical services for human factors engineering application in development, and to them for human factors basic and applied research as a continuing task in order to bring about compatibility of men and equipment. CONARC looks to the Office of the Chief of Research and Development for basic research in support of our needs. CONARC participates in projects as appropriate by establishing requirements and by assisting the units of HumRRO in many ways.

All army weapons and equipment require human factors engineering to a greater or lesser degree and the products of development are not properly engineered unless the human factors engineering solutions are sound and the equipment is man-compatible. Human factors engineering must start early in the design if money and time are not to be wasted. Emphasis needs to be laid on this point by everyone who participates in the early design stage of equipment.

In winning a war we must influence the enemy people and leadership. These are people - humans. His army is also made up of men - again humans. Our army is made up of men. They win or influence the enemy by the use of their weapons. Our armies will be most effective with better weapons. These weapons must be compatible with the men to gain the most advantage and insure winning and our survival.

E. WELCOMING REMARKS, by Colonel John E. Walker, Acting Director, U.S. Army Engineer Research and Development Laboratories

As the Acting Director of your host organization, the Engineer Research and Development Laboratories, it is my privilege and pleasure to add just a word of welcome today. My organization, as well as the Post itself - the Commanding General, General Wilson, is with us this morning - is at your disposal to make this visit as pleasant and pleasurable as possible. The schedule for this conference is rather full and allows no time for you to visit our facilities at the Laboratories. So I would also like to take this opportunity to invite you to visit us individually after the conference at any opportune time which you may find. We would be most happy to have you and we think that we have a whole lot to show you. Thank you very much.

CHAPTER 2
U. S. ARMY CORPS OF ENGINEERS PRESENTATIONS

A. VISION TRANSFORMS and ELEMENTARY DECISION MAKING: John J. Johnson, U.S. Army Engineer Research and Development Laboratories

B. PRACTICAL EXAMPLES OF HUMAN FACTORS IN DESIGN OF EARTH-MOVERS: John H. Hyler, LeTourneau-Westinghouse Company

A. VISION TRANSFORMS AND ELEMENTARY DECISION MAKING by John J. Johnson, U.S. Army Engineer Research and Development Laboratories

INTRODUCTION

Over a period of many millions of years, the human visual apparatus has evolved into a complex and wondrous mechanism with a high degree of performance over a dynamic light range of ten orders of magnitude. However, modern warfare, with its emphasis on night mobility and night combat operations, demands a night vision capability on the part of the fighting soldier considerably in excess of that provided by biological evolution.

Since 1942, the Corps of Engineers has been sponsoring the development of electronic vision tubes for both the intensification and storage of low light level images. Figure 1 shows some of the image intensifier tubes which have come into existence as a result of this development program. These tubes have evolved from applied research in the fields of photoelectricity, phosphors, secondary emission, electron optics, ultra high vacuum, and glass to metal technology. The initial tubes had light gains of .5 to 5. In the early fifties this was extended to 15 and 25 in the unipotential series of tubes which are today used in weaponsight, vehicular driving and tank gunnery applications. In the late fifties, the tube cascading technique was perfected and noiseless electronic vision tubes with light gains of 50,000 to 1,000,000 made passive viewing under starlight illumination possible. These tubes have extended the threshold of vision for electro-human vision systems during darkness to light levels 1000 times below the threshold of the ordinary unaided eye. The new electronic vision tubes allow the soldier to fire weapons and drive vehicles at night under starlight illumination without the use of active light sources.

This paper will discuss a method of performance analysis which considerably simplifies the calculation of the decision making properties of electro-human vision systems and which allows the optimum human matching and synthesis of such devices for a variety of military applications.

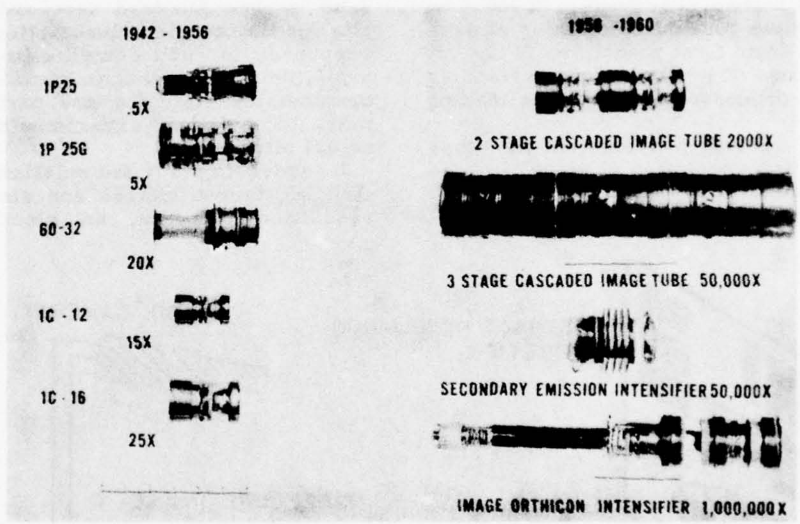

Figure 1. Electronic Image Intensifier Tubes Developed by The Corps of Engineers

VISION TRANSFORMS

An electro-human visual device may be considered as in the nature of a communication channel coupling a military target message such as a tank located in object space to a human network with interpretive and decision making properties. The complete system in shown in Figure 2.

It is possible to postulate that the decision making process does not contain of continuum of values but is restricted or quantized into five distinct states of activity. These are:

1. Negative response
2. Target detection
3. Target orientation detection
4. Target class recognition
5. Target type identification

In other words these are the five elementary degrees of freedom of the overall electro-human vision system. Obviously the probabilities associated with these decision states

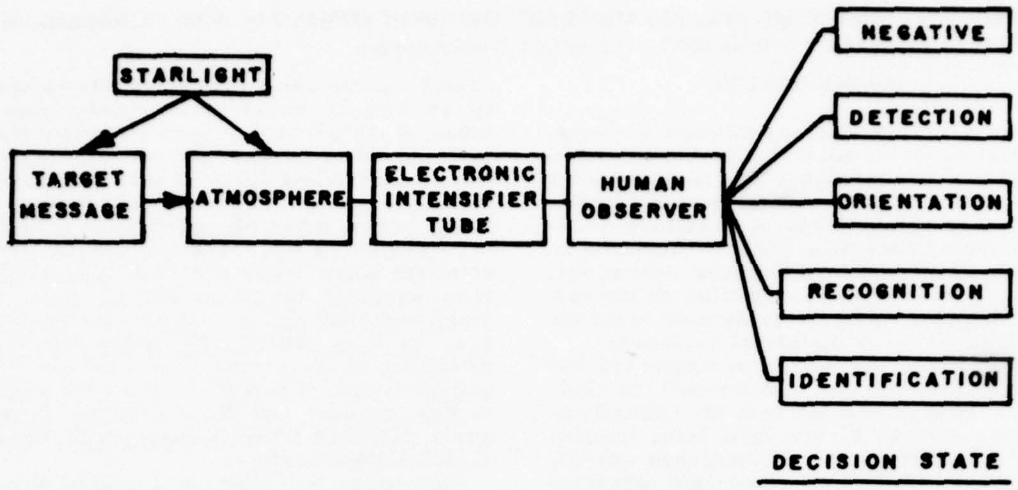

Figure 2. The Electro-Human Vision System

depend on the characteristics of the optical target message, the properties of the electronic intensifier device and the physiological responses of human observers. It must be stressed that the general calculation of such probabilities from first principles is not yet possible because of the limited understanding of the visual processes and decision making apparatus.

One of the central problems in the study of the human interpretation of visual images is the complexity of description of such images. The target message which comprises the input signal in the visual communication channel requires two spatial and one intensity dimensions and some ten thousand to one hundred thousand information bits for its complete description. The human responses to such complex images are not available from the known visual functions and the decision state for any particular image must be obtained experimentally from the actual situation.

In order to study the relationship between complex target images and simple abstract resolution patterns, an electronic image

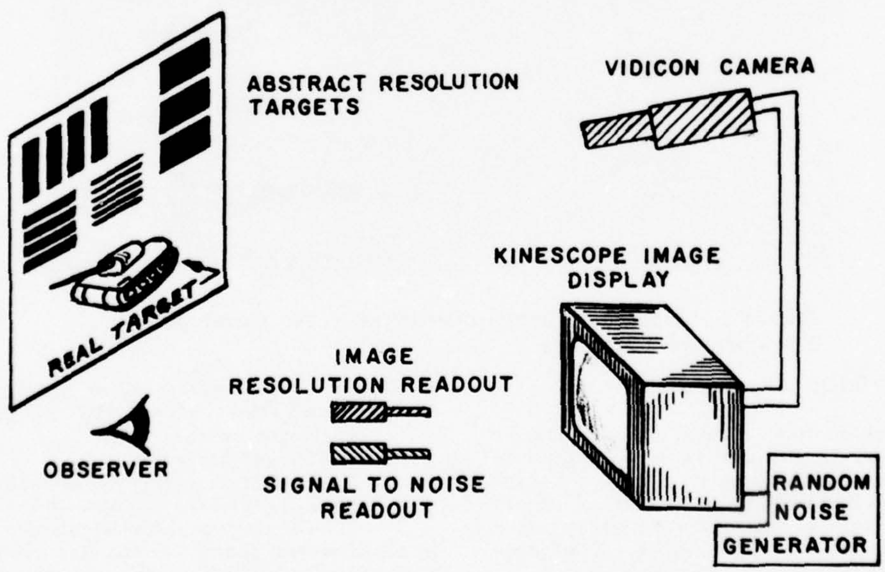

Figure 3. Electronic Image Analyzer

analyzer and synthesizer was developed. This apparatus is shown in figure 3 and consists of: (1) real and abstract target input messages; (2) a vidicon camera for image pickup; (3) an kinescope image display unit equipped with external noise generator and resolution and signal to noise instrumentation. This set up permits the generation of both real and abstract images with independent control on scale, contrast, resolution and time dependent shot noise.

Both intuitively and logically it seemed a relationship should exist between the linear resolution of an electro-human vision system and the decision state of that system. Measurements with out of focus images on the electronic image analyzer have established a relationship between the spatial interval resolved at the target and corresponding decision states of detection, recognition and identification. For instance in the tank target plane viewed normally, a spatial interval resolution of ten feet suffices for target detection while target identification requires a spatial resolution of 1.2 feet. Expressed in such absolute units, spatial interval numbers differ from target to target. It has been found that the quasi invariant image transform numbers may be formed by expressing the space interval resolution in terms of the minimum projected exterior dimension of the target. The procedure for a tank target is shown in figure 4.

The minimum exterior dimension of the projected image is used as a decision yardstick since this dimension has a decisive effect on the luminance energy in an image perturbed by poor resolution. A vision transform therefore defines the necessary and sufficient resolution required for a particular decision level. Additional conditions are that the brightness and contrast for the real image must be made equal to that of the abstract pattern. The resulting transform numbers are independent of distance, contrast brightness and practically of target form. They indicate the linear relationships which exist between the decision states of an electro-human vision system and the ability of that system to resolve abstract resolution patterns of varying spatial frequency. In effect, a vision transform of a target effectively replaces the complex target as the input into the electro-human vision channel and therefore very considerably simplifies the complexity of analysis.

As might be suspected, the transform numbers do depend on the angle of view of the target. In figure 5, the angular transform distributions of a tank image have been plotted for various decision states against the view angle. For view angles greater than 45°, the resulution required for recognition and identification decision states increases by 200-300% over the normal incidence resolution.

In figure 6, the normal incidence transforms of four different military targets are tabulated. Over an error excursion of ± 25%,

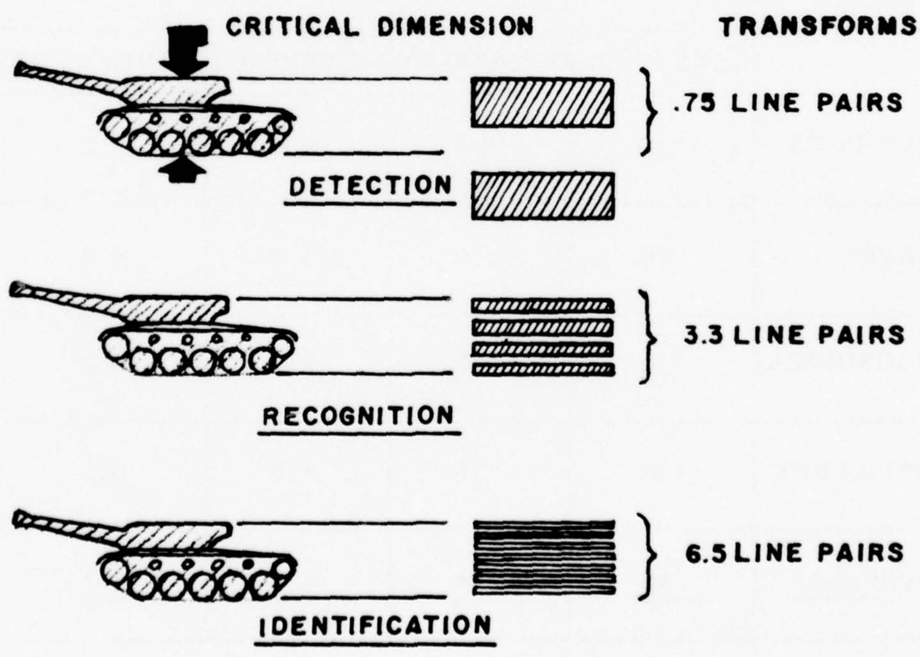

Figure 4. Tank Image Transformations

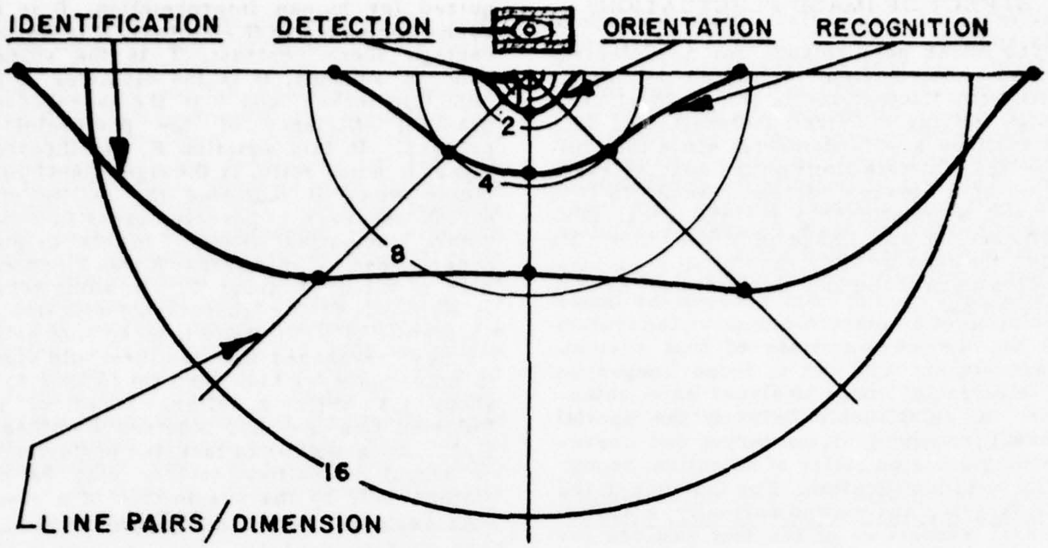

Figure 5. Angular Image Transform Distributions

simple transform numbers relate directly to decision activity for a variety of military targets. Integration of all view angles would result in somewhat greater transform differences from one target to another. In any event, vision transforms do allow the determination of the decision making state of any electro-human vision system since it is only necessary to determine the angular resolution of the system.

TARGET	TRANSFORM FREQUENCY PER CRITICAL DIMENSIONS			
	DETECTION	ORIENTATION	RECOGNITION	IDENTIFICATION
VEHICLES	1.0	1.4	4.0	6.5
TANKS	.75	1.2	3.5	6.0
PERSONNEL	1.1	1.5	4.5	8.0
ARTILLERY	1.0	1.5	4.5	6.5
AVERAGES	.95	1.4	4.1	6.7

Figure 6. Normal Military Target Transforms

EFFECT OF IMAGE FLUCTUATIONS

The ideal performance for any electro-human vision system is limited only by the statistical fluctuations in the photo-electric image leaving the first photocathode. Such fluctuations are fundamental since they impose the ultimate limit on the angular resolution of a viewing system. Rose[1] in 1948 derived a relationship for the ideal performance of any image pickup device. He found that the angular resolution of an ideal electro-optical pickup device may be expressed by

$$a = \sqrt{\frac{5K^2 \times 10^{-3}}{BC^2 D^2 T \theta}} \text{ minutes} \quad (1)$$

where a is the angular resolution in minutes, K is the threshold signal to noise ratio required for human interpretation, B is the scene luminance in ft.-lambert, C is the percentage scene contrast, T is the storage time in seconds, D is the diameter of the object in inches, and θ is the averaged-out quantum efficiency of the photo-electric process. In this equation K, the threshold signal to noise ratio, is the significant human factor since it indicated the ability of a human observer to perceive order in a randomly fluctuating image. In his original paper, Rose estimated that K was a constant, with a value of about 5. In some recent experiments in our laboratories with images perturbed by artificially induced shot noise, we have measured that the threshold signal to noise ratio for high contrast images to be about 1.3 while R. Clark Jones of the Polariod Company has obtained K values of 1.22. As a matter of fact, the performance of actual intensifier devices may be explained only by the assumption of a visual signal to noise ratio threshold below two.

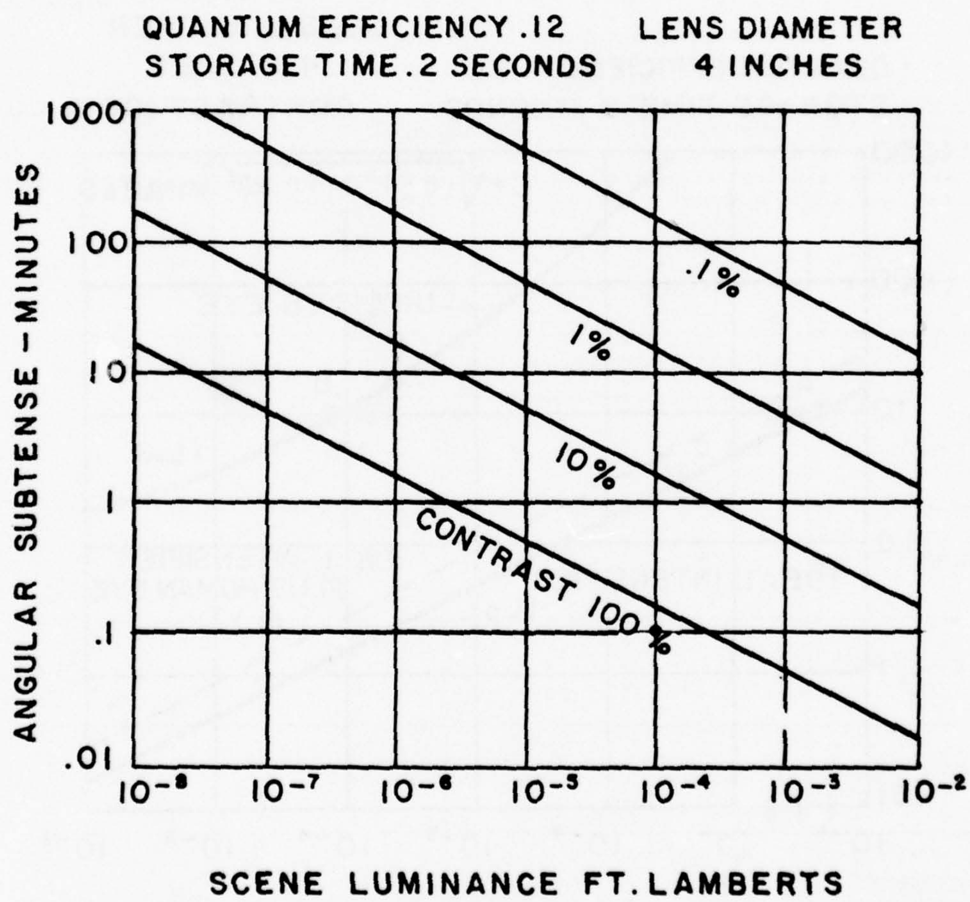

Figure 7. Angular Subtense Performance of an Ideal Intensifier

[1] A. Rose - Advances In Electronics - Vol I. 1948

Using the value of K of 1.3 it is possible to calculate from equation (1) the ideal performance characteristics of an electro-human intensifier device. In figure 7, the threshold visual subtense in minutes has been plotted against scene brightness for a wide range of scene contrast. The value of quantum efficiency, storage time and lens diameter shown in this figure were selected to approximate typical conditions. It should be noted that ideal image intensifiers are capable of extracting useful visual information from scenes at 10^{-8} and 10^{-9} ft.-lamberts brightness levels. This is 100 to 1000 times darker than the brightness levels encountered under starlight conditions. Presently available electro-visual pickup tubes approach in performance at low light level to within a factor of 2 to 4 of ideal performance. It is interesting to note that presently available electro-visual pickup tubes approach in performance at low light levels to within a factor of 2 to 4 of ideal performance. Their high-light performance however falls one to two orders of magnitude below the limits imposed by ideal operation.

ELECTRO-HUMAN VISION PROBLEMS

A rather important problem in the field of electro-visual pickup devices is the amount of light or brightness gain such tubes should provide for optimum human matching. The cost of image intensifier tubes is roughly a function of the light gain which may vary between 10^2 and 10^6. In figure 8, the angular performance functions for an ideal intensifier, the system have been plotted against scene luminance for a contrast of 100%.

Here

L_p = ideal intensifier function (minutes)

L_α = unaided eye function (minutes)

L = electro-human vision system (minutes)

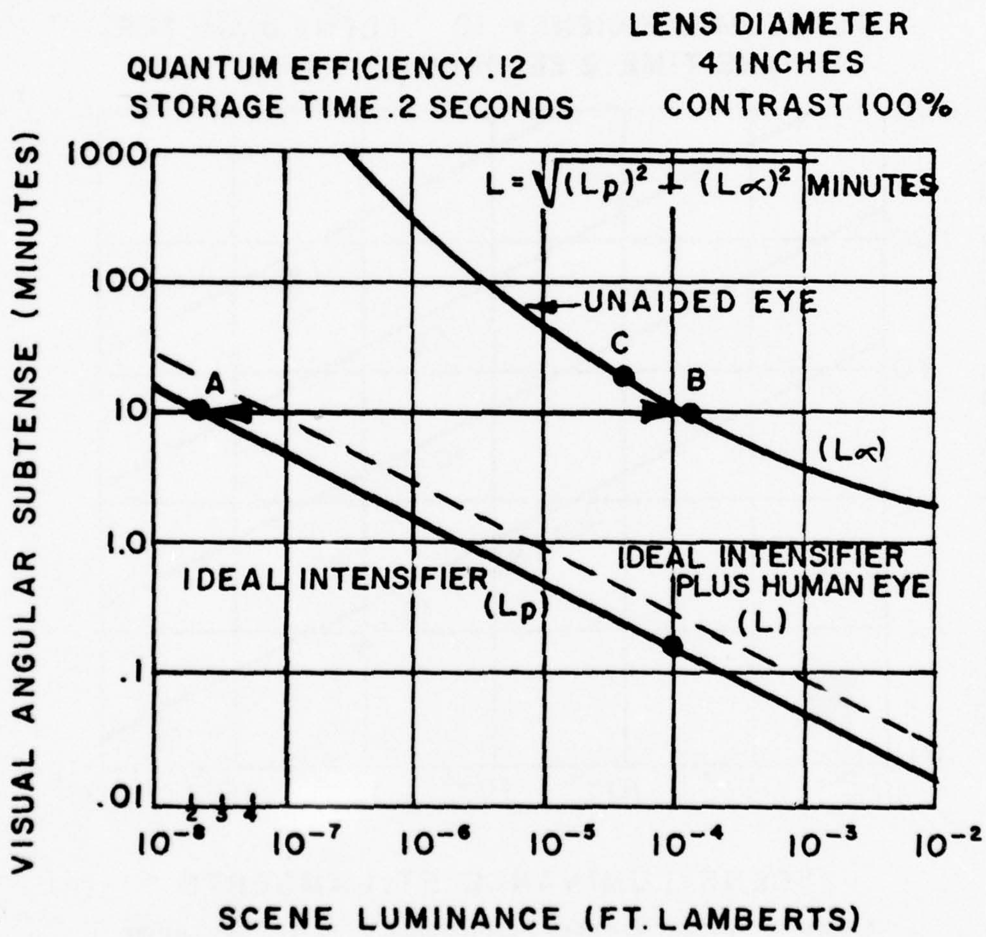

Figure 8. Visual Acuity Functions for an Ideal Intensifier and the Unaided Eye

From the theory of cascaded apertures, it is possible to express L as

$$L = \sqrt{(Lp)^2 + (L\alpha)^2} \quad \text{minutes} \qquad (2)$$

This shift to the right in the dotted curve in figure 8, from the ideal performance function indicates the loss in system resolution which results from the use of a human observer. Over an angular subtense region of from 1 to 100 minutes of arc, the ideal intensifier is about 10,000 more sensitive than the average unaided eye. Ideally the human eye should not limit the angular perception of an electro-human vision system at all.

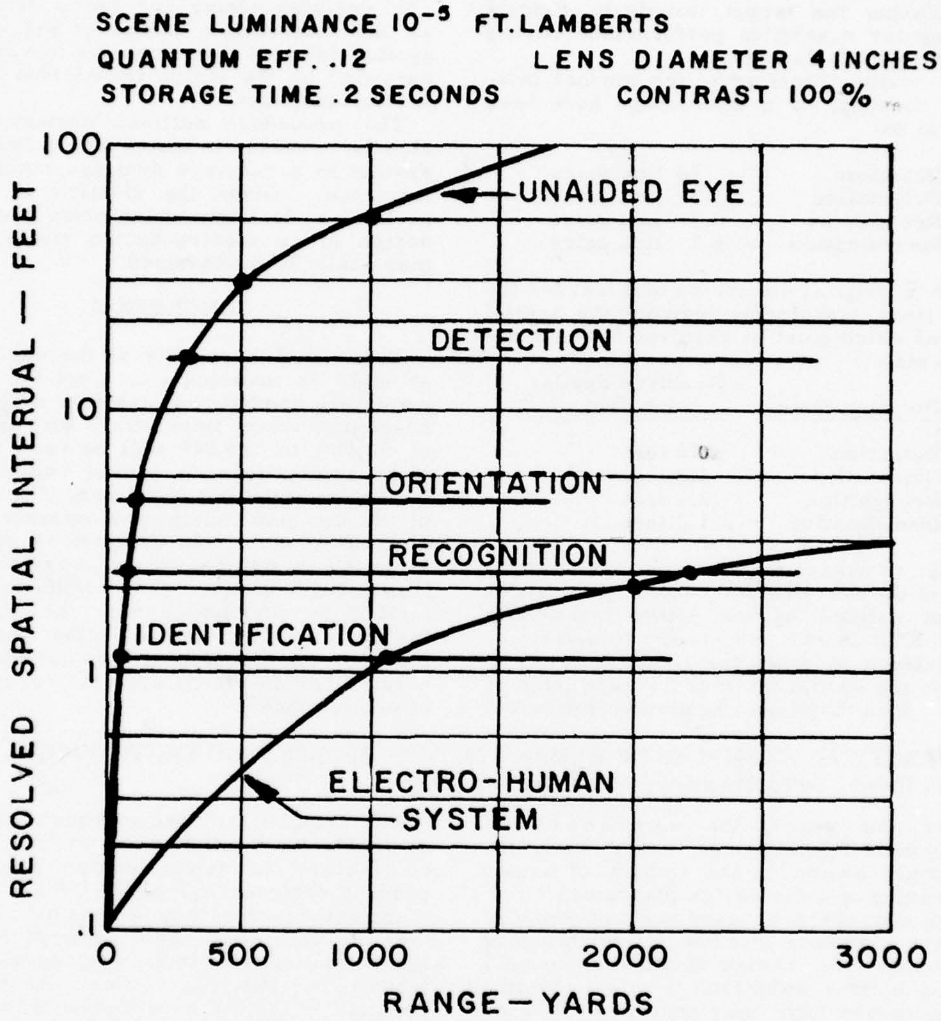

Figure 9. Decision Functions for the Unaided Eye and an Ideal Intensifier

For this condition to be satisfied for an intensifier operating at point A, for one minute of arc resolution, the brightness gain in the intensifier must be high enough to drive the human angular resolution to a somewhat greater resolution than one minute. This occurs in the vicinity of point B on the unaided eye curve. The amount of system brightness gain required to go from image input point at A to the output operating point at B is about ten thousand. Since the objective has an optical transfer efficiency on the order of 10 percent, this implies an overall light gain of one hundred thousand times to achieve optimum operation in an electro-human vision device. This is true only for a system magnification of unity. If the magnification was two the output visual angle is

multiplied by two and the operating eye point is shifted to C. The required brightness gain (AC) is now about three thousand and a lumen gain of about 30,000.

Eventually, the question must be asked as to the performance of the overall electro-human vision system from the point of view of its ability to make elementary decisions as to the nature of target messages. This is accomplished in a straight forward manner by utilizing the target transform concept and angular resolution performance curves for light pickup devices.

The vision transforms, for normal incidence viewing, of a tank image have been found to be:

Detection	.75 line pairs
Orientation	1.5 line pairs
Recognition	3.3 line pairs
Identification	6.5 line pairs

With a critical dimension of 8 feet for the tank, these transforms indicate the spatial interval which must be resolved for each decision state.

Decision State	Resolved Spatial Interval
Detection	10.6 feet
Orientation	5.3 feet
Recognition	2.4 feet
Identification	1.2 feet

In order to assess the decision making capability of the overall electro-human intensifier system defined by the dotted function in figure 8, it is only necessary to determine the distance at which the vision system will resolve the spatial interval for each decision state. Such functions are plotted in figure 9 for both the electro-human vision system and the unaided for a scene luminance of 10^{-5} F.L. and 100% contrast. Such decision diagrams directly indicate the decision making capability of vision systems. The superiority of the electro-human vision system over the unaided eye is obvious since it permits, for the above conditions, target decisions to occur at range distances about 25 times greater than with the unaided eye. The decision states are easily determined as the intersection points of the resolved spatial interval functions and the numbers specified by the vision transforms for that particular target.

The procedure outlined previously may also be reversed to match an electro-human system to a required decision making performance. Given the distance at which a particular decision state must occur, the design of an electro-human vision system may easily be synthesized.

CONCLUSION

The visual capability of the unaided eye at night is inadequate to meet the present and future combat requirements of the army. Electronic image intensifiers with light gains of 50,000 to 100,000 will be used in many night applications to extend human vision by factors of 10 and 100 times. The analysis of the decision making performance of such electro-human vision systems is very considerably simplified by the use of the vision transform concept. The vision transform method in conjunction with the statistical theory governing image fluctuations allows the optimum matching and synthesis of electro-human vision systems for a variety of applications.

B. PRACTICAL EXAMPLES OF HUMAN FACTORS IN DESIGN OF EARTHMOVERS by John H. Hyler, LeTourneau-Westinghouse Company

Over the years, the engineers at LeTourneau-Westinghouse have been increasingly aware of the impact of human engineering on their design problems.

Basically, we have used the reactions of our test engineers and our equipment users to identify the human factors apparently needing further attention. I might mention that instances have been observed where an operator came to work in his air-conditioned Oldsmobile, put on fresh, clean coveralls and climbed aboard our equipment to move dirt under a broiling sun. It's not surprising that we sometimes receive suggestions concerning our products. We recognize that however clever our designers may be in inventing and developing basic equipment that provides superior performance and dependability, they have not <u>nearly</u> done their job unless proper consideration has been given to the people who will use that equipment.

You may be familiar with the competitive demonstrations often used by earthmoving contractors to select equipment. If the product designer has neglected certain human factors, this may be largely offset, for the duration of a sales demonstration, by highly skilled operators working rather intensely for that short time. As a result, practically the full capabilities of the equipment may be observed in spite of the design deficiencies. Though an <u>initial</u> purchase be based on a sales demonstration, additional units of that model are considered on the basis of the overall performance <u>after</u> the demonstration, working month after month in the contractor's operations and using his own drivers and maintenance personnel.

It is really the operator who sells additional pieces of the same model to his boss. He does this first by the actual production rate he is able to maintain with the no more

than reasonable application and effort he expends on the job. He sells more directly when the question of additional machines is discussed. It is then, if not before, that he voices his own reactions to the equipment he has to live on eight or ten hours a day. Human engineering considerations are essential to the development of any successful product design.

Let's consider very briefly some of these areas where a human problem has been recognized and corrected.

CABLE CONTROLS

Probably the outstanding deficiency on the older earthmovers, both tractor drawn and rubber tired, was the high lever and pedal forces required to control this large equipment. The cable control unit that was widely used to power the various functions in the self-loading scraper is perhaps the best example of this. This cable control unit was a mechanically driven winch arrangement on the tractor, normally with two drums and fairleads. Since the clutch actuation was effected by manual force from a lever, with no booster system, the line pull available on the cable was mainly determined by the effort exerted by the driver. The brake actuation was provided by a heavy spring, so that a load once hoisted into position could be maintained without further attention from the operator. Yet, when it was desired to release or lower the load, it was again necessary for the operator to supply adequate force at the handle to overcome this large brake spring. I'm sure that handle forces on the order of 80 to 100 pounds were not uncommon, and some were higher. Even though the average driver of such an earthmover had developed rather substantial arms and shoulders, it obviously was impractical to use such a cable control device for the newer and larger earthmovers being developed. Assuming that no relief were to be offered the operators from the high handle forces, it would have been possible to increase the earthmover size with that cable control unit by just multiplying the lines of cable used, to supply the larger forces required. This was not desirable because the actuating speeds would be decreased even more than indicated by the comparative forces required, because of the greater inefficiency of multiplied lines of cable. The higher horsepower, higher speed earthmovers under development rather required <u>faster</u> actuation to obtain balanced performance.

We, therefore, began some time ago to develop a power system that would require very little effort and the minimum of attention by the operator, and would provide other very desirable features as well. This is the simple, rugged alternating current electric control system used with such great success in recent years on our products. We will confine our remarks here on the advantages obtained with this system to the human aspects.

1. Finger-tip control by simple, rugged switches requires only four pounds force to actuate, yet handles the full engine horsepower as needed.

2. The lever actuating the switch is <u>large enough</u> to be easily operated by a mittened hand and <u>strong enough</u> not to be easily damaged by any excess pressure from the operator.

3. The switch arrangement is self centering so that upon release, the actuation stops. This is excellent for control of fairly short cycle operations. Whenever desired, to relieve the operator from holding the switch in on longer cycles, a holding coil is built into the system so that the motion continues after once being initiated by the operator. In this case the motion in that direction is stopped either by the limit switches for that function or by the opposite direction of motion being indicated by the operator.

4. Identification of controls is readily obtained. The compact switch arrangement makes it easy to group all related controls together. Within a group of controls, they are also easily placed in the same standard arrangement as used throughout the equipment, making it unnecessary to read the names on the controls, once you are acquainted with this order. Variations in shapes on the control levers are also used in some cases to aid in identification.

5. Excellent control while operating over rough terrain is possible. This is because a hand rest is provided right at the finger-tip controls, so that movements of the driver's body (other than within his hand) have practically no effect.

6. Since these switches can be mounted in almost any position, it is easy to install them so that the direction of operation on the finger-tip control corresponds to the direction of the function that results. This is not only easier, but much safer in the event of sudden driver reaction to an emergency.

7. Machine controls can be mounted in any desired location to provide the most efficient overall operation for the driver both looking forward, or looking back at the trailing equipment.

8. Because of their compactness, many controls can be placed in desirable relationship to the operator. As an example, we have had three earthmovers, each of 32-1/2 tons capacity, all towed like a train behind one tractor. Electrically powering and controlling all the necessary functions is no problem.

The only item out of this list where the old cable control unit comes close to the new electric control is its ability to withstand the maximum effort of the operator.

Particular attention is given to controls that are essential to the safe operation of these earthmovers, such as steering and stopping. They are studiously arranged so that the normal reaction in an emergency will provide the correct control, and are made in most cases to operate exactly as on a passenger car or truck. In addition, they are built with sufficient strength so that if a driver panics and exerts very high forces on these controls, they will safely handle this loading and continue to function properly. By giving the operator complete confidence in the safe and dependable control of his vehicle, his performance is improved and the machine capabilities are more completely utilized.

TRANSMISSIONS

Another problem that has been with us ever since the development of higher speed rubber tired earthmovers is the shifting of the transmission. The early production units were equipped with a heavy duty truck-type sliding gear transmission. Trucks normally roll on some kind of roads, and reasonable time to shift gears is available. In spite of the benefits of the larger rubber tires that were used, the high rolling resistances encountered in off-the-road work demanded extremely fast gear changes. This was particularly true in the lower gears. Although it might be possible to negotiate a situation in a higher speed gear, it was not possible to complete an "up" shift before rolling to a stop.

The best performance was obtained with the operator who had some combination of the most skill and the most strength. The skill was needed to sense the best timing in coordinating engine speeds, clutch operation and gear shifting with the under-foot conditions and terrain. The strongest arm and shoulder was needed for "cramming" the transmission in gear in spite of being not properly synchronized. This obviously was an undesirable situation from the human engineering viewpoint as well as some others. Even though such a transmission worked very well on the highway, it presented real operating problems for earthmoving.

We therefore began designing power shifted transmissions for our construction equipment to overcome these deficiencies. These were subsequently built for our earthmovers, which to the best of our knowledge were the first such production transmissions for this purpose. This development eliminated the need for a high degree of skill to shift gears and removed the heavy requirements for human strength and endurance to complete some gear changes. Gear shifting is controlled simply by moving a gear selector lever to the position representing the speed desired, with only a few pounds force required, no clutch pedal, and nothing to synchronize. The control positions are in a simple sequence, from neutral through successive forward speeds as the lever is moved forward, and into successive reverse speeds as the lever is moved to the rear from neutral.

This arrangement is widely used today in the earthmoving industry and apparently represents pretty close to the optimum between operator convenience and maintaining control of the vehicle.

Even though the power shifted transmission was available, and very successful, many customers preferred to continue with the sliding gear type of transmission because of its simplicity and efficiency. In order to obtain improved machine performance and to try to give some help to the operator, additional transmission speeds were incorporated, making the ratio between adjacent gears smaller. Also, transmission brakes were offered to permit more rapid synchronization of the sliding clutches. This latter item requires some additional skill, but tends to reduce the forces required on the gear shift lever.

A much better answer meantime was under development, which has just in the last few months been getting into the field. It is the same basic sliding gear transmission in all its simplicity and efficiency, to which has been added a shifting control device. This arrangement senses when the gears are properly synchronized and slides the splined clutch into engagement at the correct instant. Thus a high degree of skill is no longer needed. Neither are the large lever forces required of the operator. Ths control arrangement can be made just about as simple and convenient for the driver as on the previously mentioned power shifted transmission. With this shifting mechanism available on the sliding gear transmission, it will no longer be necessary for any equipment user to make a choice that will sacrifice human considerations. Whether the task to be performed is better suited to the power shifted transmission with torque convertor or to the sliding gear type, the desired equipment can be made available without such a compromise.

SUSPENSIONS

One of the first things that became apparent as we began to develop high speed earthmovers was that the driver took considerable punishment. A more or less standard type seat cushion apparently was adequate for crawler tractors even on rough terrain since they moved so slowly. But with rubber tired construction equipment capable of moving at 30 miles per hour or better, the vehicle speed and therefore its performance, was limited in rough going because of the very

rough ride suffered by the driver when using the seats that were available. As a result, we designed our own seat for this service, incorporating about a one foot deep foam rubber cushion. This seat has done an excellent job of absorbing the very severe jolts the operator would otherwise take, yet has practically no rebound to throw him out of the seat. This provides a very pleasant, nicely damped ride on reasonably rough surfaces. We have observed from personal experience that as a result, performance on rough terrain is limited principally by the driver's ability to hold on and stay in the seat.

More recently, a further gain has been made in this area. This is the "Hydrair" suspension which is used on our knuckle-steered trucks and tractors. Basically it is a wheel suspension in the form of a piston and cylinder which provides an air spring to carry the load and an arrangement that provides an air spring also for rebound. Built into the same device is a hydraulic reservoir, orifice and passages which contribute the required damping for the suspension. Softness and capacity of the suspension can be varied as needed to tailor it to a specific machine or application.

Because of the variation in rate, a very soft spring is provided in the normal working range. At the same time, under the most severe conditions the suspension never "bottoms." This device has proven in actual service to be of great benefit in permitting operation over uneven ground at even higher speeds because of the greater comfort and assurance for the operator.

VISIBILITY AND OTHER FACTORS

In addition to establishing efficient working positions for pedals and controls, considerable attention is given to visibility. Vision to the front of the vehicle is provided to the maximum practical in keeping with other requirements, so that the driver need not proceed timidly for fear that something is hidden ahead of the nose of his vehicle. Also, he must be able to readily see his instruments or indicators, plus the important areas of the machine behind him. Further, the driver should be able to see close by the wheels on either side of the machine, permitting him to proceed with confidence at the maximum practical speed even on the edge of a fill. We commonly use mock-ups to confirm that these factors are satisfactory.

It is possible for a designer to get into trouble by making everything too easy or too convenient for the operator. For instance, we have often been concerned with the high pedal pressures required to operate the master clutch. For this reason, many vehicles use some power booster arrangement to assist the operator, particularly if the pedal pressure is seventy-five pounds or upward. It is easy in such a case to err in making the pedal too light, so that a careless driver lightly resting his foot against the pedal proceeds to slip the clutch and burn it up. For this reason we prefer not to use less than about 40 pounds force to move the clutch pedal.

Another example is in regard to the ether starting aids commonly used for diesel engines. If it is very conveniently placed for the driver, he may elect to use it as a temporary power booster for his engine, particularly if he is driving a rig with a sliding gear transmission and is almost able to climb over the brow of the hill without changing gears. I can assure you that the charge of ether that sometimes is given the diesel in lieu of shifting gears doesn't help the engine one bit. They are not made to take that kind of loading for very long. We, therefore, make it a practice to place the ether injector where it is not handy to reach when driving such a machine.

MAINTENANCE FACTORS

Though the operator is the fellow that we are principally trying to satisfy and assist in our human engineering consideration, there is another man we must also recognize; the mechanic or maintenance man. We, therefore, check each new machine model to make sure that regular servicing or adjustment points can be easily reached, and that provisions are made to take care of major items of maintenance in a reasonable manner. We make sure that there is space for the mechanic to work and that extreme reaches are not required. We have among our test personnel those that would approximate the 95th percentile both in large men and small, so that the result is fairly acceptable.

One of the design approaches that we began several years back is component replacement as a package. This permits the mechanic to replace a major component in minimum time in the vehicle. He is then able to repair that component under more nearly ideal conditions in the shop rather than lying on his back in the mud. He thus is not inclined to rush through an inferior job because of the unsatisfactory environment and because of the pressures imposed upon him when the equipment is tied up in repair too long instead of working.

One of the ways we try to accommodate the mechanic is to keep the number of wrench sizes to a minimum. If this is taken into account early in the design, it is possible to produce a very practical vehicle where most of the requirements can be covered with just a few wrenches. This simplifies and expedites his work, since the chasing after special or in-between sized wrenches is minimized.

Again, it is possible to get into trouble if the designer goes overboard in making things too handy or too easy. For instance, if adjustments very seldom need be made, the means of adjusting should not be placed in some location where it will practically invite anyone with a screwdriver to give it a twist. The tinkering of all the amateur mechanics is not nearly so likely if such an adjustment is less accessible, or if it is an unfamiliar item which they know they don't understand.

A second instance of the designer being too much help in making things easy is in the selection of screw sizes. Normally, we select the smallest diameter that is practical for a given job, since much less effort is required to "torque up" such fasteners. Generally we have been able to keep our thread diameters on bolts and capscrews around 1-1/4 inches and smaller. If this same philosophy is carried down into the small diameter bolts, we may end up with some fasteners that would almost be in a watchmaker's category. If the mechanic who has been servicing the rest of a huge earthmover is so fortunate as to find a wrench small enough to fit that tiny screw, he will no doubt promptly twist it off the first time he tightens it, and wonder why it broke so easily. We, therefore, try to assist the mechanic by keeping the fasteners within a reasonable range of sizes. We prefer to keep the smallest sizes of fasteners used for joining or mounting parts on the equipment at 3/8 inch diameter, but do tolerate sizes down to 1/4 inch. Smaller diameter fasteners are used only inside small components where anything larger would be impractical.

BALANCE IN THE PROCESS OF DESIGN

After our design engineers develop a new concept, based on our experience with similar equipment, it is reviewed. All interests of the company are represented, including many departments who are close to the operations in the field. They are thus in a good position to confirm that the human factors of concern to the users have been given the desired consideration in the new concept.

Yet, the most important contribution is made if the designer can adequately put himself in the role of the operator. It is particularly necessary that the design engineers be familiar with that type of equipment, how it will be used and the sequences, methods and cycles that are employed in its operation. Our designers observe earthmoving jobs in the field to keep in touch with today's requirements and techniques in the hauling and construction business. They also operate such equipment on our proving ground and in the field. Additional information is fed back through field engineering, service and test personnel. This permits the designer to rather effectively put himself in the operator's shoes, and helps him to experience and understand what the operator wants and why he wants it.

After the new product has been designed and built, it is turned over to our Engineering Test Section. Their reports include the human engineering aspects of the vehicle. Naturally, on some occasions the designer is not inclined to accept the test engineer's criticism, particularly when the opinion rendered cannot easily be supported by some numerical data. In such a case the designer will often convince himself one way or the other by spending a couple of days operating the machine in typical fashion on the proving grounds. I recall one such instance on a vehicle some time back, where the test engineers had complained that a tractor transmission was even harder than usual to shift. It might have been possible to run comparative tests with other equipment and tabulate the data, even though the shifting forces would vary according to the skill used on the shift, speed of shift, rolling resistance and grade.

A more effective argument was to have the designer operate the experimental vehicle through adverse conditions with the fast shifting that was required to keep the machine rolling. Before completing the first day of such testing, he complained that as a result of that gear shifting his hand looked more like hamburger. He had already concluded that there must be some way to improve that condition, and very shortly thereafter he found ways to do so.

The same technique is used in checking ease of maintenance, with the test engineers sometimes inviting the designer to come out and demonstrate first-hand how the servicing is to be readily done in the field. The designer often returns quite greasy, but convinced that he has another problem to solve.

We do not have time this morning to consider the many other human factors that we know we must recognize in product design. No doubt there are areas that you could point out that have been overlooked or neglected to date. Some of you can likely predict additional considerations which will influence our future designs.

Besides the human factors, we must also be concerned with performance and machine dependability. The probability of machine failure is related not only to the quality of design and construction, but also to the complexity of the equipment. Since the probability of some failure occurring increases rapidly as the machine incorporates more parts, it is desirable to keep the equipment just as simple as possible. Simplicity and reliability are, of course, of tremendous importance in military equipment.

The product we design is merely a tool to extend man's capabilities. The operating personnel must be recognized as the key part of the team. The machine design should use the human capabilities as well as the machine's characteristics to provide a balanced working unit.

On the one hand we maintain that the full vehicle performance should be attainable without more than reasonable effort and application by the man. At the same time, we insist that the equipment should not be unnecessarily complex (and low in reliability as a result) just to relieve the operator of some functions that he could readily handle. However, this latter position may be qualified by customer preferences.

In the final analysis, our success or failures in developing successful product designs of high performance equipment depends upon our securing the desired balance between machine dependability and the human engineering factors.

CHAPTER 3
U. S. ARMY ORDNANCE CORPS PRESENTATIONS

A. LOW AND HIGH LIGHT LEVEL ELECTROVISUAL PROBLEMS: Morton L. E. Chwalow, Frankford Arsenal, Philadelphia, Pa.

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A. LOW AND HIGH LIGHT LEVEL ELECTROVISUAL PROBLEMS by Morton L. E. Chwalow, Frankford Arsenal, Philadelphia 37, Pa.

Significant progress has been made in the past two years in extending night fire control capabilities to the darkest conditions of illumination via the use of electrovisual equipment. Furthermore there is a growing need for the use of electrovisual aids for daytime battlefield use.

Frankford Arsenal has been actively engaged in efforts directed toward the accomplishment of passive night fire control under project DA 511-02-062 commonly called Project EVE.

Studies conducted during 1956 and the early part of 1957 indicated that a worthwhile approach to the problem lay in the direct modification of standard television pickup tubes and the straight-forward extension of standard television techniques. The advent of the Z5294 image orthicon pickup tube early in 1958 substantiated this approach. Further efforts sponsored by Frankford Arsenal have resulted in the Z5396 tube of much greater sensitivity.

The intrinsic sensitivity of the tubes employed has been increased by a factor of more than twenty and increased capabilities for the amassing of energy with minimal loss of resolution have also been attained.

The pickup tubes referred to in the above paragraph are dimensionally and functionally identical with standard image orthicons and can be made available in production quantities from at least two sources.

In late 1957 work was started on tank lash-up equipment. This equipment immediately became the workhorse of both the laboratory and the field.

Its purposes were to prove the feasibility of the EVE approach, to aid in the determination of design techniques and parameters for future equipment and to indicate future operational requirements.

The pickup tubes noted above have demonstrated, that even within the limitations of lash-up type equipment (incorporating f/2 optics), night-fire control is possible under any conditions of so-called starlight illumination yet encountered with no more than five seconds storage time[1].

Improved field and laboratory test equipment is scheduled for delivery during the summer of 1960.

EVE equipment was successfully used by the Submarine "U.S.S. Skate" on its epic sub-polar voyage to view through the surface ice layers from depths of as great as 400 feet, for the purpose of surfacing.

Efforts to provide a user test tank prototype have been under way since the fall of 1959. Delivery is scheduled for FY 61.

The introduction of night fire control electrovisual equipment in vehicles introduces significant human factors engineering problems.

In the first place no discussion of night fire control systems requiring the amassing of information for periods of even a few seconds, can be held without first stating that such a requirement is basically undesirable. In a sense, all the immediate and advanced research and development efforts to increase pickup sensitivity are directed toward the elimination of any need for storage.

The need for storage requires the insertion of a flicker eliminator in the system in order to offer an uninterrupted display to the operator. This adds considerable complexity. However, the need for storage can be traded off with the speed or f-number of the optical system. Viewing an object under any conditions of illumination requires high quality magnification sufficient to provide an image with adequate information so that, in the case of fire control, a gun can be laid on it with the required accuracy. In the case of the existing and readily producible components, the following table shows typical amassing times required for a variety of optical systems.

The figures are based on the experimentally-observed data obtained with the lash-up.

The figures in the table below are conservative, they are based on observations with the lash-up, at best an old system, operating below peak efficiency, and incorporating a patched-up flicker eliminator. New test gear is scheduled for delivery during the summer of 1960 and the above observations will be repeated.

The table shows that by using low f-number optical systems we are approaching the point where flicker-eliminators may become

Range (yds)	Field of View (o)	Focal Length (Inches)	Diam. (Inches)	f/n	Time in Seconds Z5294	Time in Seconds Z5396
1000	5.5 x 7.3	10	5	f/2	5	2.5
1000	5.5 x 7.3	10	10	f/1	1.25	0.63
2000	2.25 x 3.65	20	10	f/2	5	2.5
2000	2.25 x 3.65	20	20	f/1	1.25	0.63

[1] Tests at H field APG, Fort Knox, and Fort Devons on moonless nights.

unnecessary, particularly when one considers the use of persistent phosphor monitors. The human factors involved in using a rapidly flickering system for night fire control must be evaluated.

Another human factors engineering point must be made in this discussion. The use of magnification must limit the field of view. The field of view requirements for various types of functions from search through gun laying to driving must undergo serious study.

The fields of view expressed in the preceding table are those associated with equipments capable of accomplishing gun laying with accuracies equal to those available in present daylight fire control systems. It is understood that the commanders search fields can be at least double those shown, and drivers, if found desirable, as large as required. Further, if shorter range operation is required, similar remarks apply. Technically the above denotes that for the commander, for example, optics of about half the focal length and aperture diameter with equal light gathering capabilities than that specified in the above table can be used with the electrovisual components now readily available.

It is noted that the technical step which must be taken to increase the field of view and, simultaneously, reduce the size of the optical aperture for both the commander and the gunner is the development of pickup units inherently capable of greater resolution with the maintenance of high contrast over the entire image plane. If cascaded image intensifiers are used, magnetic focus must be employed and provisions must be made to obtain maximum gain per stage to minimize the required number of stages.

Present EVE systems have resolution capabilities of 600 and 800 TV lines in the tank. TV Systems having 1200-line resolution, have been constructed in the laboratory with existing image orthicons.

Efforts to develop a miniaturized image orthicon will be inaugurated in early FY 61. Miniaturization of the image orthicon is in itself desirable, but more important, if successful, it may provide for increasing the overall resolution capabilities of the I. O. type tube and which would make possible systems with wider fields of view and corresponding smaller objective optics.

In delivering this paper the attempt has been made to report to you the significant gains made during the past two years in attaining night fighting capabilities, particularly under the approach of project EVE.

It is well known that the approach taken in project EVE has stimulated significant gains over a comparatively short period of time. In closing, however, it is well to strike a cautionary note. The Ordnance problem of providing passive night fire control at lowest conditions of illumination is prime; the technique used to accomplish this purpose is secondary and dependent on a variety of considerations. Continued research on all approaches directed toward accomplishing the basic Ordnance purpose is indicated.

The introduction of any electrovisual equipment brings with it its associated human factors engineering problems. Some of these have been pointed out in this paper. More important is the stimulation of your thinking on the human factors engineering problems associated with the application of such equipment.

B. DETECTION OF RANDOM LOW-ALTITUDE JET AIRCRAFT BY GROUND OBSERVERS

by William Wokoun, U. S. Army Ordnance Human Engineering Laboratories, Aberdeen, Proving Ground, Md.

I'd like to tell you, today, a little bit about the aerial detection study which the Human Engineering Laboratories conducted out at Gila Bend, Arizona, last September.

The basic question we tried to answer was this -- how well can an unaided man, without any special electronic or optical equipment, detect aircraft that are coming in toward him? Now of course this question isn't brand new. People have been interested in what happens when a man goes out and looks for planes for a long time. But the emphasis has shifted quite a bit over the years. For example, during World War II, the man might have been the only way you had to detect aircraft. There wasn't any alternative, because electronic detection devices hadn't arrived on the scene yet. The problems then centered around the question of -- how can we optimize the man's search? What can we do to make him just as efficient as possible? The answers to these questions were things like finding the best search procedure -- the best optical aids for a given situation -- or finding a way to pick out the people who can do this kind of job better than the average man. But the man was still a necessary part of the scheme.

Today the question is different. Now we have a choice -- we can still try to detect aircraft by having a man look for them -- but in addition, we have very effective electronic equipment which may pick up aircraft much better than a man could, but which may pose some other problems -- such as cost, weight, maintenance, and the like. Because of factors like this, the man may still be the best choice -- provided he can perform as effectively as the rest of the system requires him to. And this is why our basic question

arises. Before you can say whether or not the unaided man is "good enough" at detecting aircraft -- you have to find out just how good he is.

Of course, the first place that you start looking for information about what the man can do, is in the professional literature. And because this problem has been around for some years, in one form or another, you might expect the literature would contain an answer. Surprisingly, this isn't the case. Earlier work in the area, as we've just seen, was aimed mostly at improving the man's performance -- rather than finding out just how well he did perform. There have been some studies more recently that tried to pinpoint the ranges of which a man will detect aircraft. But what generally happened in these studies, we felt, was that the subjects knew a little bit too much about when and where aircraft would appear. Obviously, if the observer knows about when an aircraft is due -- and approximately where it's coming from -- his job becomes a lot easier. His job could become so easy that all he has to do is set his alarm clock -- remember where to look -- and he'll sight all the aircraft when they're 10,000 yards or so away. But this kind of information doesn't tell us much about what'll happen in a tactical situation. Aggressors are sneaky critters, and some people even think they're downright difficult. They just don't co-operate -- they try to sneak up on observers -- come in at an unexpected time from an unexpected direction, if they can. And if we want to find out how well an observer can deal with these sneaky-type tactics, the aircraft in the experiment have to be sneaky, too.

Now the situation where a man goes out to look for aircraft -- that are trying to outwit him -- is plumb complicated. There are all kinds of variables. And when you make a list of the variables and think about them a while -- you keep saying to yourself, "Gee whiz, all of these things make a difference -- they're all important." Realistically, tho, you just can't study very many variables in any one experiment. Each variable has to be randomized or counter-balanced against all the other variables -- and this means that, for every new variable you decide to study, you have to about double the number of observations. So -- out of this tangled basket of snakes -- we have extracted two of the variables that seemed most significant -- first, the size of the sector the man has to watch -- and second, the altitude the aircraft is coming in at.

So far as sector sizes go -- we can point out the two extremes immediately. On the one hand, you could have a man watch the entire horizon -- all 360 degrees -- and make him responsible for sighting any aircraft that comes in from anywhere. Or you might assign a whole bunch of men -- working as a team -- to cover the 360 degrees -- so each man would be watching for planes in just one small sector. Tactically, it seems like either one of these extremes might make sense. In flat terrain, you might very well have one man searching 360 degrees. And, on the other hand, some places there's only one reasonable course for aircraft to use -- MIG ALLEY was a good example. So it's very important to know what effect sector size has -- because just by changing the size of the team, you might be able to improve its detection capability quite a bit.

With a variable like the size of the search sector, it seems logical to say that -- there is some best search sector size . . . and that if you have a man search a bigger sector -- or a smaller sector -- his performance will be degraded somewhat. You can see why this would happen. If you give a man too big a sector to search -- chances are he's not going to be able to cover it too well. He can only look in one direction at a time -- and if he's looking in the wrong direction when a plane comes in, he may not spot the plane until it's very close. But if you give the man too small a sector, he's apt to get bored -- just not pay close attention -- and who can blame him after he's been staring at that same tree on the horizon for an hour.

The important thing, then, is to sample a wide range of sector sizes - to find the range where detection performance will be best. We did this by sampling four sector sizes -- 360 degrees, 180 degrees, 90 degrees, and 45 degrees -- and then putting enough men at each site so that, among them, they covered the entire 360 degrees. For example, at the first site, there was one lone man who was responsible for searching the entire 360 degrees. At another site, there were two men, each searching 180 degrees. Then four men, each searching 90 degrees. And, finally, eight men, each searching 45 degrees.

Now as you recall, the second experimental variable was aircraft altitude. How high a plane is - has a lot to do with how visible it's going to be. Even when we ignore the fact that trees and such like will mask out a very low plane -- the low plane is apt to have a terrain background, where a higher aircraft will have a sky or cloud background. If we ask what altitudes aggressor jets would probably use for attack missions, some of the information we have on tactics points to low-altitudes - very likely 2000 feet or less. The altitudes used in this study were 500 feet and 1500 feet above terrain.

Let's consider for just a moment the area where this study was done. Out in darkest Arizona, about halfway between Phoenix and Yuma, is a picturesque little oasis entitled Gila Bend. Our test site was located about 8 miles southwest of the town of Gila Bend,

at an Air Force emergency landing field. The center of the experimental complex was what we called "Ground Zero" - which was at the ramp area of the field. The four test sites were eight-tenths of a mile from Ground Zero -- in the directions north, east, west and south. The data-reporting networks ran from each site - thru Ground Zero - to a data van some five miles away. The terrain, as you probably know, was essentially flat in all directions for at least 8-10 miles - and the atmosphere was consistently clear during the time the study was conducted.

As we've already seen, it's quite important that the aircraft appear at random intervals and from random places. First of all, the time between passes had to be randomized -- because if not, the man would stand there and he would very soon figure out that planes come by every five minutes, say - or that a plane comes every 15 minutes. Once he knows this, he can detect planes much better than he could in a tactical situation. So we varied the time between flights in a random manner. Sometimes it was five minutes or less when a second plane came by - and sometimes it was as much as two hours later. This forced the subjects to keep searching, because they never knew when a plane would begin its approach.

Now it's also important to randomize the courses that the aircraft approach on. What we did was to select a series of six approach courses which were spread pretty much randomly around the compass. Each one passed directly over Ground Zero. Since we scheduled twelve flights each day, each course was flown twice -- once at the 1500-foot altitude, and once at the 500-foot altitude.

Another source of variation was aircraft. So we could collect some data on accuracy of identification, three types of jets were used -- T-33's, F-86's, and F-100's. The typical day's schedule called for four flights of each, in a random order.

Aircraft speed was held constant at 400 knots -- not because we felt aircraft speed wasn't important, but because only so many things can be varied at one time.

Finally, the selection of subjects is a very important matter. The approach here was that -- since only a small number of subjects would be used -- 15 each week during the two weeks of the study -- the subjects must be selected carefully so they'd represent an average or "normal" population.

We gave them Ortho-rater tests to see what their visual efficiency was. It measured their near acuity, their far acuity, tested them for color vision, depth perception, and so forth. From the larger group that was tested, we selected 30 subjects who had vision that was essentially good normal -- say 20/30 or better.

After the men had taken Ortho-rater tests, they took Audiometer tests to check for any significant hearing loss -- because it's quite possible that, when a plane comes in close and you're looking in some other direction, you might hear it before you can see it. The men selected had essentially normal hearing, too.

The subjects' intelligence test scores were also checked. We could make a pretty good guess that intelligence would be an important variable in aircraft detection -- because here, again, chances are that there is some one intelligence level which will do a job like this best. Chances are that if you get men who are too bright for the job, they'll be bored and their efficiency will suffer. Or if the men are too dull for the task, they just won't quite be able to cope with what they're supposed to do. However, we weren't able to investigate this variable systematically -- that would be quite an extensive study by itself -- so we held intelligence roughly constant by picking subjects who had GCT scores between 90 and 120 -- roughly the middle average range.

Now -- even tho these subjects were selected quite carefully -- they still weren't equivalent by any means. That is, man A was not exactly like man B, and neither of them was like man C. So, for this reason, it was necessary to rotate the men around to all of the sites -- so that all of the men were tested at each site -- and no man spent more time at a site than any other man did. This way, we know that whatever results we get aren't due to the fact that some one man - who may be better at detecting planes wherever he is - was at one site all the time.

To give you a little bit better feel for what happened -- here's what would happen on a typical test day.

Some time about 6:30 in the morning, the men were taken out to Ground Zero. They were given sun glasses, and copies of a silhouette chart to help them identify the three types of jet aircraft. Then the men formed into groups and were taken to their assigned sites, where they started looking for planes.

As a plane approached, a subject at each site detected it somewhere along the line. As soon as a subject sighted a plane, he did two things: he pressed a pushbutton in a small metal box he was holding, and he called out "Target". His pushbutton signal was transmitted back to the data van. There it started a stop clock, and made a mark on a pen recorder. Then, as the aircraft passed over Ground Zero, an experimenter there pushed a similar button to stop all the clocks - and make a special mark on the pen recorder. And, of course, from this information -- knowing the courses, knowing the aircraft speed; and the times that had elapsed -- we were able to pinpoint the location of the plane, at whatever time each subject detected it. So, in this way, for each site and each

trial, we were able to get the distance at which the aircraft has been detected.

Now, we were interested not only in the distance that an aircraft is detected at -- but also in the distance at which the man can identify the aircraft. As we've already seen, three types of jets were used -- and the subjects had silhouette cards to help them identify the jets. When the subject called "Target" -- the experimenter at the site started a stop watch. He kept his stop watch running until the subject told him what kind of plane it was. Then he stopped his watch -- to get a time required for identification. And of course, later on, knowing the course and aircraft speed, we were able to determine just what point this occurred at -- as well as how accurate the subject was in identifying the plane.

So much, then, for the first trial of the day. During the rest of the day, another 11 flights were scheduled -- altho the total did vary slightly from day to day, if flights had to be cancelled for safety reasons. And during this day, each subject served at three different sites, since as we've already seen, he was rotated among them.

Well, what did we learn from all this? Let's look at some of the results.

First of all, the effect of the size of the search sector. We found here that the greatest detection distance -- what you might call the best detection -- was with the two smallest sectors. The mean detection distance was something like 2800 yards with a 90-degree sector -- and a little bit more (roughly 3000 yards) with a 45-degree sector. Where the search sector is larger -- 180 degrees or the full 360 degrees -- the mean distance is about 2150 yards.

Secondly, what effect did the altitudes have on detection distances. Here the better detection ranges -- that is, greater detection ranges -- were at the low altitude. . .and, sometimes with the smaller search sectors, the low altitude mean would be as much as 600-700 yards better. At the low altitude, the group that watched 45-degree sectors gave the best performance -- they had a mean distance of about 3250 yards -- but they were more variable, too, because they had about twice as many complete misses as at the 1500-foot altitude. At the higher altitude -- 1500 feet -- the best groups were those watching 45 degrees and 90 degrees. They had a mean detection distance something of the order of 2650 to 2750 yards. And again, the groups watching 360-degree and 180-degree sectors didn't do as well. They had a mean detection range of about 2000 yards.

Something else which we'd be interested in, of course, is the effect on performance of the inter-trial interval. Now by inter-trial interval, we mean: how long it's been since the last plane came over. In other words, will a man perform better when planes are coming in pretty thick and fast, with only a few minutes in between them -- or will the man do better if he has to watch for a long time in between flights. Here we find that there is no clear trend. Depending on the size of the search sector, the relationship varied quite a bit. For the 360-degree sector, we find that the man isn't as efficient when the inter-trial interval gets to be 45 minutes or more. However, if you have the man watch 180 degrees, you find that his efficiency is greater after half an hour. With a 90-degree search sector, efficiency seems to be a little greater where there's a longer time between planes. But -- just reversing this -- as the search sector gets still smaller -- 45 degrees -- you find the man is most efficient during the first half hour or so. So it's a little hard to tell just what this effect is. It is important, tho, I think, to note that -- in contrast to some of the vigilance studies that have been done in radar situations -- the man's performance doesn't necessarily seem to deteriorate rapidly, just from accumulating time on the job.

Cross-range is a rather interesting variable. Cross range, of course, is the distance at which the plane comes closest to an observer. We hadn't originally planned to analyze the data by cross-over range -- we'd planned to have the planes come just as close in over each of the sites, as we could. However, as you've seen, because of the physical set-up, there was some cross-range -- because each site was 8/10ths of a mile from Ground Zero. So since quite a number of people seemed interested in this effect, we broke the cross-over ranges down into three groups. With a cross-range of about 400-500 yards, we get a mean detection distance of something like 2100 yards. Now, as the cross-over range goes up, to about 850 yards, so does the detection distance -- you get better detections, and the men will pick up a plane something like 3300 yards away. But interestingly enough, if you increase the cross-over range a little bit more than that -- up to, say, something like 1300 yards -- the detection range goes down to about 2500 yards.

The same kind of analysis could be done for the identification data -- that is, telling what kind of plane it is. Here we find that -- with a 400-500 yard cross range -- the IFF will be given at about 1000 yards. If we increase the cross range to about 850 yards, the IFF distance goes up somewhat - to about 1400 yards. And if we increase it still more - to 1300 yards - the IFF distance will go up slightly more - to about 1450 yards. However, you have to note here - that the IFF is close in each case to the cross-over point -- and there doesn't seem to be any evidence, really, to indicate that you'll get a better IFF distance with a greater cross-over range. It seems to be more a matter that -- as

cross-over increases -- the plane can't come in closer than a certain point, no matter how long it takes the subject to identify it.

Another important variable is IFF accuracy. The man's effectiveness depends not only on detecting aircraft - but on identifying them - and identifying them correctly. We found an overall IFF accuracy of something like 80% -- to be exact, 81.6%. We tried to break this down, then, to find out what kinds of things affect the IFF accuracy. There doesn't seem to be much effect - from the size of the search sector. So far as altitude, again there is very little effect. The important thing - so far as accuracy of IFF -- appears to be the type of aircraft. . .and we had a rather interesting combination of aircraft here. You're familiar, of course, with what these aircraft look like -- and the T-33, as you know, is very, very readily distinguishable from either an F-86 or an F-100. The T-33's two wing tanks are a dead giveaway. However, the F-86 and the F-100 are pretty easy to confuse -- as they come in directly toward you, the silhouettes are almost identical. And the results on IFF accuracy parallel the similarities between the planes. The T-33 is identified accurately 97.1% of the time, or practically always. Very, very occasionally it was confused with an F-100 -- but this, of course, was quite rare. The F-86, tho - was identified correctly only 75.7% of the time -- roughly the same figure as we get for the F-100, which was identified correctly 77.1% of the time. Primarily, as you might imagine, the F-86 and the F-100 were confused with each other. IFF accuracy, then, depends on the similarity between the aircraft the subject is trying to discriminate -- the more similar the aircraft, the more errors the subject will make.

C. A PRELIMINARY INVESTIGATION OF CLOSED CIRCUIT TELEVISION VEHICLE DRIVING by 1st Lt. Gene L. Brown, U. S. Army Ordnance Human Engineering Laboratories, Aberdeen Proving Ground, Md.

Exploded with the "Atomic Bomb" on 6 August 1945, were the concepts and conventional designs of many of the weapons of war. Not the least of these to be affected are the tanks, long time "work horse" of the Army. If tanks are to remain an operational arm of the service they must be capable of functioning, intentionally or otherwise, in radiologically "hot" areas. To protect crew members of these vehicles from the ill effects and consequent results of exposure to radiation, some radical departures from previously adequate conventional tank design are now necessary. Because of the radiological problem, the "seeing" capabilities of a vehicle operating completely "buttoned-up" becomes a new and intricate problem. A periscope designed to pierce the hull, and at the same time provide radiological protection, has many unavoidable deficiencies not previously encountered. In addition, the operator is still subjected to possible eye damage from blast flash.

PURPOSE

The use of television for visual contact with the outside, though seeming to be the answer to many problems originating with radiological protection, introduces new problems for which tank drivers might not be able to compensate. Therefore, the Human Engineering Laboratories initiated a study to determine the feasibility of such a driving technique.

The Army Mechanical Mule (M274) was selected as the test vehicle for three major reasons. First, its flat bed permitted the attachment of any desired superstructure necessary for testing. Second, any number of courses of different patterns and varying terrain could be used since its low ground pressure made accessible many areas not normally open to heavier or tracked vehicles. Third, it could be driven by anyone capable of handling a standard shift vehicle.

Controls of the Mule were modified to be compatible with future tests and to allow adequate room for the television equipment. Steering wheel, brakes, and accelerator were replaced by a "joystick" and the clutch changed from a foot release to a hand release mounted atop the standard H type shift. The joystick was used in the following manner: Acceleration was obtained by pushing the stick forward, braking by pulling to the rear and steering by left and right motions of the stick.

All television equipment utilized was commercially available and consisted of the following components. A vidicon camera was rigidly mounted at approximately eye level and just to the right of the operator's head. A $\frac{1}{2}$" focal length lens was used permitting a horizontal field of view of 45° and a vertical field of 37°. For use as a monitor, a regular 17" home portable television receiver was mounted approximately 17" from the driver's eyes at a viewing angle of 30° below the horizontal. The monitor was powered by a standard Signal Corps Power Unit (PE75). An inverter with an output of 115 V AC served as a power source for the camera which required a more stable input than could be obtained from the generator.

Since familiarity with terrain and road conditions was a definite advantage to the drivers, each specific phase of the study had its own course.

Course #1 was a secondary road with adjoining trails. Since it was relatively easy to negotiate and at the same time required maneuvering of the vehicle, it was chosen as the course for familiarizing the subjects with the vehicle's controls.

Course #2 was one requiring precision driving by the subjects and consisted of a $\frac{1}{2}$ mile circular course ending with a land of flag-tipped stakes. Each driver was required to complete the circular portion four times and each of the lanes once.

Course #3 was a secondary road with a trail through a wooded area and across an open field. In general, the terrain was level with very wet, muddy trails containing deep ruts. For a vehicle of this type as modified, the course was considered cross-country requiring greater driving skill than either of the two previous courses.

DISCUSSION

Visual driving for the purpose of familiarizing the subjects with the vehicle controls was conducted on Course #1. After $1\frac{1}{4}$ hours, each subject was confident of his ability adequately to control the vehicle in any normal situation. During this initial driving period, average speed was recorded as 14 mph with each driver stalling the vehicle only once or twice. A requirement for driving the Course several times was placed upon the subjects in an effort to familiarize each with the terrain and road conditions. It was thought that the advantage of comparing known conditions with their appearance on the monitor might introduce clues for determining conditions while traveling unfamiliar terrain later in the study.

It is important to note that the television equipment used was commercially available off-the-shelf items and was in no way ruggedized. Equipment mounting utilized no shock absorbing techniques and the "Mule's" only resistance to road shock is its rubber tires. However, the equipment successfully withstood the shock and constant hammering received throughout the study without serious damage. Proper shock mounting and normal advancement in the field of ruggedized television equipment, should produce components capable of withstanding the road shock and constant vibration encountered aboard a tracked vehicle, and also provide the operator with a more stable picture.

Existing problems, such as the loss of depth perception and color cues decreased in importance as the study progressed. Through experience, the subjects learned to compensate for such losses, as was shown by their judgments while driving through patterns and close quarters. Another problem was that of premature maneuvering when negotiating curves. This was partially corrected through training and could probably be eliminated by adding pan and tilt capabilities to the camera.

The vidicon tube in the camera was damaged when subjected to direct sunlight. This was prevented by placing a shield over the camera and a filter over the lens. There is also, a definite need for an automatic iris to compensate for changing light conditions.

SUMMARY

I would like to emphasize that this was a preliminary investigation to determine the feasibility of such a driving technique. Initially, the subjects were skeptical of the system; however, after a few hours of driving their attitudes changed and they became confident in their ability to control the vehicle. One subject felt that with 15 or 20 more hours of training, he could drive anyplace. We can't share this opinion at this stage of development; however, we feel the system warrants further consideration. Attention should be given to virtual image systems, higher resolution systems, and stereo-presentation.

FUTURE STUDIES

The next step in this series of studies will be conducted in a modified M-48 Tank. Initially, a modified supine driver's position will be tested and evaluated. The second step will utilize television as the means of observation while operating the vehicle in this position. A 17" monitor will be mounted approximately 15" from the driver's eyes. This time a higher resolution system will be used in an attempt to present a more detailed picture. The camera will be ruggedized and be capable of pan and tilt, which will assist the driver when negotiating curves. The lens will permit a 53° horizontal field of vision.

There will be an automatic iris to compensate for changing light conditions and a filter to prevent tube damage by direct sunlight. There is no provision for driving during the hours of darkness; however, this area is being explored by other agencies. The generator will provide the stable power output desired and the entire system will be shock-mounted on the tank. This equipment will be subjected to vibration and shock while the vehicle is being driven over extreme terrain features. The data received from this series of investigations will provide us with both basic and refined parameters of driving in a supine position using closed circuit television as a visual device.

D. VEHICLE CONFINEMENT STUDIES by Samuel A. Hicks U. S. Army Ordnance Human Engineering Laboratories, Aberdeen Proving Ground, Md.

Among current investigations being conducted by the Supporting Research Laboratory of the U. S. Army Ordnance Human Engineering Laboratories, a major project has the purpose of determining the effects of prolonged confinement on the crew and passengers of tracked vehicles. Toward this purpose, a series of studies have been carried forward to investigate the effects of prolonged confinement in Armored Personnel Carriers on the performance of Infantry personnel.

A question might be raised as to why the intense interest in this area of research? This question is best answered in reference to the dominant mobility concept now stressed in the organization of all branches and services of the Army. Because of this mobility concept and the associated probability of operating under the threat of chemical, bacteriological or radiological attack, it may be necessary for troops to live and fight for long periods of time from the confines of armored personnel carriers and other armored vehicles. This anticipated prolonged use of armored vehicles raises serious questions as to the ability of the crew and passengers to withstand the adverse environmental conditions present and still emerge as a fully effective fighting unit.

In attacking this problem, it was first necessary to determine what our objectives were. Generally, I think these have been adequately stated by the U. S. Continental Army Command in a research request dated 22 August 1958. They are:

1. "To determine the physiological and psychological limitations and capabilities of individuals operating in tanks and armored personnel carriers for sustained periods of time.

2. "In order to assist in vehicle design, determine the human limits of tolerance to temperature, noise level, carbon monoxide, vibrations, cramping and motionless periods, shock from hits on vehicles and blast effects from atomic weapons.

3. "Determine the psychological and physiological tolerance limits of personnel operating in tanks and armored personnel carriers under ideal weather conditions as compared with unfavorable conditions such as rain, snow, heat, dust and periods of limited visibility.

4. "Determine what training is necessary to increase the individual's ability to operate in tanks and armored personnel carriers for sustained periods of time under the previously listed conditions.

5. "Determine the effect of short rest periods on increasing the individual's ability to withstand adverse conditions in armored vehicles.

6. "Determine methods of measuring the tolerance of individuals to these conditions."

It should be obvious from these objectives that this program is an extremely broad one embracing not only the areas of applied experimental psychology and physiology but also the areas of personnel selection and training. With this in mind, the personnel of the Human Engineering Laboratories have attempted to come to grips with a general approach so that the problem areas embracing selection and training will be readily available to those agencies that are cognizant in these fields.

Briefly, then the purpose of this paper is to discuss with you:

1. The results of completed research in this area.
2. Current research, and
3. Plans for the future.

The general approach to this problem has been one of investigating the effects on performance of gradually increasing the length of time of exposure. This is done primarily to avoid the risk of permanently harming any of the test subjects. In addition, the utilization of this technique will enable the investigators in determining relative changes due to an increase in the length of time of exposure. At this time two studies have been completed investigating the effects of 4 and 8 hour confinement periods in a maneuvering armored personnel carrier.

The initial study in this area was conducted in January 1960 and investigated the effects of 4 hours confinement in the M59 armored personnel carrier. The subjects consisted of 50 enlisted men of the 2d Battalion, 3rd Armored Cavalry Regiment of Fort George G. Meade, Maryland. For experimental purposes, the subjects were divided into 5 squads of 10 men each, including squad leaders. Four squads were designated as experimental, while one was utilized as a control.

Four courses were designed by laboratory personnel and used as personnel test courses. These courses are as follows:

1. Obstructed-Run Course. This test was designed to measure gross-motor coordination and stamina. It is a planned course of 220 yards in total length. The course in addition consisted of:

a. Four 10-foot wide ditches
b. 30 yards of staggered automobile tires
c. A 30 yard banked straightaway
d. 40 yards of staggered 4 x 4's
e. 30 yards of $2\frac{1}{2}$ foot hurdles

There was a 10 yard unobstructed area between each series of obstructions.

2. Grenade-Throw Course. This course was designed to measure eye-Arm coordination and consisted of nine 4-foot square sand pits and a throwing line 25 yards from the center of the targets.

3. Rail-Walking Course. This course was designed to measure equilibrium. A single test pattern consisted of one rail, 9 feet in length by four inches in width, one rail, 9 feet in length by two inches in width and one rail 6 feet in length by one inch in width. These three rails were arranged in a triangular pattern. The test area consisted of 9 such test patterns.

4. Rifle-Fire Course. This course was designed to measure rifle accuracy. It consisted of 2 banks of M31A1 Trainfire Target Mechanisms. Each bank consisted of 9 targets placed at distances of 100 to 150 yards from the firing line and 20 to 25 feet apart. The targets were controlled and scored from a point behind the firing line.

In addition to these four courses, the Tracked-Vehicle-Cross-Country Test Course was used as the treatment course. This course is a permanent proof facility at Aberdeen Proving Ground.

A treatments-by-subjects experimental design was followed throughout this study. This design enabled the investigator to utilize each subject as his own control, that is, the pre-confinement performance of each subject was compared with his post-confinement performance. Prior to the administration of the pre-confinement tests, 3 practice trials were administered to the experimental group. Trial 4 was the first trial of record or the pre-confinement trial and was followed by the 4 hour period of confinement. Trial 5 was the post-confinement trial, thus the actual investigation centered around a comparison of the subject's performance on Trial 4 as opposed to Trial 5. The same procedure was followed with the control groups. The single difference being that they were not confined to the vehicle. They were, however, restricted to their living quarters between Trials 4 and 5.

In following this procedure, it was first assumed that in general the performance of the experimental subject would exhibit a gradual trial to trial increase in proficiency. Secondly, the use of practice sessions would serve to decrease the variability among subjects, thereby lending greater reliability to any performance loss observed after the 4 hour period of confinement for the experimental groups. And, finally, the proficiency of the control group would follow the same pattern and would either continue to increase or remain the same during Trial 5 as compared with Trial 4, thus yielding an additional base for comparison. Any decrease observed in this group's performance could probably be attributed to chance.

Prior to the administration of any test, standard instructions were read to all subjects. After the instructions were read and before the first trial, a demonstration was run by a proctor to show exactly what was required on each test. Scheduling of each test was arranged so that no more than one test was introduced to a squad during any one work period.

On each day that an experimental session was scheduled, the pre-treatment session was given immediately before entering the personnel carrier. The lone exception to this occurred in the case of the Rifle-Fire Test. In order to have approximately the same conditions of illumination for the pre- and post-treatment administration of the Rifle-Fire Test, these measures were taken on successive days. The pre-treatment measure was taken at approximately the same time the post-treatment measure was to be taken on the following day.

After each pre-treatment session the subjects were loaded on the vehicle. At this time all means of exit from the vehicle were closed and the driver was instructed to open the vehicle only in the event of mechanical trouble or injury to one of the subjects. At the completion of the 4 hour ride, the personnel carrier returned to the test area, the subjects dismounted and were immediately run through the post-confinement session.

The data from each test were subjected to an analysis of variance. Analysis of variance is a statistical technique for determining the significant contributions of a number of factors to the complete set of data. In this instance we were attempting to determine the effect of the confinement period on the ability of the individual to perform the 4 experimental tasks.

The results were as follows: First with regard to the Rail-Walking Test, both time and weighted distance scores were obtained. The weighted distance scores were standard scores obtained from raw scores of the actual distance traversed on each rail. Through this technique the most difficult or narrowest rail received the greatest value. The experimental group traversed less distance after confinement than before confinement. This is demonstrated in the pre-confinement mean of 129.6. The analysis of variance indicated that the observed decrease between distance scores of the experimental group was significant beyond the 1% level of confidence. As anticipated and by contrast, the control group showed a slight increase in distance traversed in this trial. The Trial 4 mean time score was 63.5 seconds while the Trial 5 mean time was 66.2 seconds, yielding a mean increase of 2.7 seconds for the experimental group. On the other hand, the control group exhibited a mean decrease of 4.2 seconds.

These differences are only cited as indicative since they were not statistically significant. It should be pointed out here however, that even though the increased time score exhibited by the experimental groups was not statistically significant, it may mean more than any of the other measures for it actually represents an increased time to cover a shorter distance. Conversely with the control group a decrease in time accompanied an increase in distance traveled.

In reference to the Rifle-Fire Test, scores based on number of hits out of 18 rounds fired were collected. Before confinement, the average number of hits scored by the experimental group was 9.1. After confinement, the average number of hits was 6.6. This loss of 2.5 is statistically significant beyond the 1% level of confidence. However, in the case of the control group the Trial 4 average was 8.1 while the Trial 5 average was 8.5. Here again the results followed the predicted trend exhibiting a decrease in the performance of the experimental groups and virtually no change in the control group.

The Obstructed-Run Test yielded two sets of scores. These scores were total time taken to complete the course and the number of obstacles missed or more specifically, time and error scores. The time score served primarily as an index of stamina and the error score served as an index to gross-motor coordination. Before confinement, it took the experimental group 71.5 seconds to complete the course; after confinement, the mean time was 77.3 seconds. This 5.8 second gain is by virtue of analysis of variance statistically significant beyond the 1% level of confidence. By contrast, the Trial 4 mean time for the control group was 76.2 seconds, while the Trial 5 mean was 78.9 seconds. While there was a slight increase of 2.7 seconds, this increase is not statistically significant.

The Obstructed-Run error scores followed a similar trend. For the experimental group, an increased error score of 2.9 was exhibited. This resulted from a pre-confinement mean of 4.6 and a post-confinement mean of 7.5. Analysis of variance showed this increase between treatments to be significant beyond the 1% level of confidence. The control group error scores showed a decrease of 1.0. This decrease is not significant.

The final test of the battery, the Grenade-Throw Test was intended to yield scores based on the number of hits out of six grenades made in a 4-foot square target box. The number of hits made in the target however, was relatively small. On only 4 occasions did a subject score more than two hits, and this was achieved by only 18 subjects out of 72 for the experimental groups. On 30 occasions no hits at all were recorded. Based on these results, it was concluded that the test as constructed was much too difficult to yield satisfactory comparison between pre- and post-confinement trials. Nevertheless, even with the inadequate test there is an interesting indication. The pre-confinement total of hits for the experimental group was 40, while the post-confinement total was 27, as compared with Trial 4 total of 16, and Trial 5 total of 13 for the control group.

The second study in this program investigated the effects of 8 hours confinement. The vehicle used on this occasion was the M113 Armored Personnel Carrier. Essentially the same procedure was followed here as was adhered to in the initial investigation. There were, however, several refinements that were introduced to increase the precision of the experiment. First, in addition to the four tests administered previously, all subjects underwent pre- and post-confinement audiometric testing. Second, during this investigation, modification of the Grenade-Throw Test was accomplished. Finally, samples of air composition and temperature were obtained.

The results of this investigation followed the same general trend as was reported for the 4 hour study. Analysis of variance showed statistically significant losses in Rail-Walking distance scores, Grenade-Throw hit scores and Obstructed-Run time and error scores. While a loss was observed in the Rail-Walking time scores, this decrement was not statistically significant. However, when the time score is converted into a rate per unit of time, the difference between pre- and post-confinement scores is highly significant.

For this sample of subjects, the Rifle-Fire Test was too difficult under the present experimental procedure so that these data were not sufficient for statistical analysis.

It was previously mentioned in connection with the initial study that the Grenade-Throw Test in its original form was too difficult for the experimental population. In light of this, the throwing distance was decreased to 20 yards. This distance proved to be more within the capabilities of the experimental population, thus yielding some usable data. The mean pre-confinement hit score was 3.2 and post-confinement mean was 2.3. This difference is statistically significant beyond the 1% level of confidence. Furthermore, to emphasize this difference, it may be added that 16 of 20 experimental subjects showed a decrease in post-confinement performance as contrasted with pre-confinement performance.

In addition to the test battery described above, all subjects were given a limited audiometric screening test using a standard Maico model audiometer. All were tested with a pure tone at 4000 cycles per

second before being subjected to confinement. Since hearing losses tend to reach a maximum for frequencies in 3000 to 6000 cycles per second range, hearing loss at 4000 cycles can generally be assumed to be due to noise exposure. The noise inside the M113 ranged from 110 to 123 decibels with a mean value of 115 decibels. These values were derived from 40 observations on 2 vehicles. Upon completion of the 8 hour exposure, the 54 subjects were retested at the 4000 cycles per second level. Recovery time for the subjects ranged from 30 minutes to 40 hours. A comparison between Test 1 and Test 2 showed no appreciable hearing loss at 4000 cycles.

As a further check, 10 of the fifty-four original subjects received complete audiograms covering all of the test frequencies. These ten men were retested upon completion of the noise exposure period after a recovery period of 30 to 45 minutes. A comparison of test results did not indicate any loss of auditory acuity.

At the end of the eight hour period of confinement, an air analysis was made of the gases inside of the APC. Interpretation of the results is difficult for invariably the drivers would crack the driver's hatch at some time during the 8 hour period. However, indications are that air pollution might be a problem during longer periods of confinement. The carbon dioxide concentrations were decidedly elevated over normal air concentrations, even though the driver's position was open. Normal atmospheric concentration of carbon dioxide is .03%. The measured concentration of carbon dioxide was .4%. In addition, the O_2 concentration was consistently low by 4 to 5%. This, plus the elevated carbon dioxide concentrations are definite evidence of poor ventilation and is also indicative of an air pollution problem that may be present in future studies.

Even though it is not and cannot be accounted for in the treatment of the data, perhaps one of the most important contributing agents to our performance decrement is nausea. While it is generally felt that the occurrence of nausea is due to the pitching and rolling motion of the vehicle as it maneuvers cross-country, many subjects subjectively reported that this state may be a function of food eaten during the period of confinement or the presence of some noxious fumes. It might be added here, that more nausea was observed by crews of the M113 during the 8 hour period than of the M-59 during the 4 hour period.

The most frequent complaint of the subjects however, resolved around the cramping caused by the limited space and a concomitant loss of circulation in the lower limbs of the body. This factor, if severe enough, may have been the major contributing factor to the decrements observed in equilibrium and locomotor coordination. If true, this variable should be isolated and studied in the future.

Taken together, the two studies reported herein indicated that:

1. There may be a significant loss in firing accuracy.
2. There is a decrease in stamina and motor coordination.
3. Equilibrium is significantly impaired.
4. Eye-arm coordination shows a significant decrement.
5. There may be a problem of air pollution in periods exceeding 8 hours.

While the results followed the expected trend, it is not practical at this time definitely to conclude that the observed decrements would result in serious impairment of the performance of Infantry personnel assigned to an armored personnel carrier in a combat situation. It may be entirely possible that the effects of the periods of confinement observed here are of an extremely transient nature.

It is anticipated that future effort in this area will be pointed toward determining the effects of periods of confinement ranging up to and possibly beyond a 24 hour period. This research will be aimed at ascertaining that point at which a practical decrement occurs. Any effort beyond this point will attempt to resolve those factors responsible for the observed decrement and mitigate these factors. In addition to the armored personnel carrier, this program will be extended to include tanks and any other vehicle with which the probability of sustained confinement exists.

E. EXPERIMENTAL INVESTIGATIONS OF A WEAPON SYSTEM CONTROL MECHANISM*
by C. A. Karr, Frankford Arsenal, Philadelphia, Pa.

[Unclassified abstract of a classified presentation]

Investigations were made of 2 aspects of the control mechanism of a Heavy Anti-tank Weapon System. One study investigated the influence of different amounts of friction in the controlling mechanism. The second study concerned the influence of different

*Authorized persons may obtain the full text of this presentation by appropriate application to: The Ordnance Corps Human Engineering Laboratories, Aberdeen Proving Ground, Maryland.

control ratios within the mechanism. An account was provided of the experiment as well as the findings in terms of army operation.

F. HUMAN FACTORS ANALYSIS OF AN AUTOMATIC CHECKOUT DEVICE by Harold R. LaPorte, Jr. Autonetics Division of North American Aviation, Inc, Downey, California.

The Autonetics Human Engineering Unit was formed two years ago. The unit's activities are typical of most industrial human factors groups, ranging from advanced studies and experimental research to operator panel design. The largest portion of the unit's activities, and perhaps the most important, has been devoted to working directly with system and design engineers to develop equipment designs that are more easily and efficiently operated and maintained.

As an example of the unit's activities, a typical equipment design problem has been selected for description. This problem will also provide a realistic background for acquainting those present, especially those who represent the users of military equipment, with some of the major practical problems faced by an industrial human engineering group. Several areas will be pointed out wherein military organizations can be of greater assistance to industrial human engineers in ensuring that maximum pressure is exerted on the design engineer to regard human factors requirements as a basic part of design, just as he regards other military specifications as necessary design features.

The chosen problem involves an automatic checkout device called the programer-comparator. A simplified example may serve to convey quickly the concept of automatic checkout.

Envision a complex weapon system, a missile in this case. Assume that within this missile are 1000 test points, each of which provides information about the performance of a part of the missile. In order to certify that the missile is ready for flight, a technician must check the information at each test point.

Assume, furthermore, that it takes the the technician three minutes to find the right test point, select the proper equipment, make a reading, compare the reading with a normal value, and decide whether it is in or out of tolerance. Also, assume that the technician never becomes tired or distracted. It would require at least six full working days for the technician to complete the missile checkout.

Now, suppose instead that leads from each test point in the missile are connected to cables. And suppose that the technician's test instruments are placed in a box that can be connected to the missile cables. Within the box, in addition to the test equipment, are a switching matrix, a comparator, and a data input device such as a tape reader. This box can be made to do all of the things the technician did in checking missile performance. If the machine can check a test point once each second (a conservative estimate), the missile checkout would take about 16 minutes, a considerable improvement over the technician's six-day effort.

The programer-comparator is similar to the machine just described. It is tape-program controlled and can check equipment as small as a modular unit (for example, a pluggable circuit board), or as large as a complex weapon system with many more test points than the missile just described. The equipment can be used to check production items in the factory or as an integrated system tester at the maintenance depot.

The programer-comparator checks weapon system performance at two levels. At one level, it controls the operation of the system and then senses, on a go/no-go basis, the completion of each operation. At a more detailed level, equipment performance is checked by measuring selected parameters such as voltage or frequency at preselected test points within the system. Obtained values are compared with expected values stored in the programer-comparator's tape program to give a measure of performance.

The programer-comparator is referred to as automatic even though it requires an operator. However, once the machine is started, it can sequence through an entire checkout program of many hundreds of tests, selecting test points within the weapon system, measuring, comparing, and evaluating without operator assistance. The operator's task is extremely simple; he is needed to apply and remove power, load the tape programer, and start the test. In addition, he monitors the progress of the checkout by means of status indicators. A printer provides a permament record of test results.

To increase the usefulness of the programer-comparator in unusual test situations (for example, the R&D phase of a weapon system where weapon system tolerances have not been precisely established) and as a troubleshooting aid, provision is made for manual programing.

The type of checkout equipment represented by the programer-comparator has become an important part of modern weapon systems. Some of the major advantages of this type of equipment may be summarized as follows:

1. It saves time. As shown in the illustration, the programer-comparator can perform in milliseconds, tasks requiring several

minutes for a human to perform, and can continue without rest for long periods.

2. It provides reliable measurements and decisions. The machine is not subject to fluctuations in accuracy exhibited by men using test equipment. Precise definition by the weapon system design engineer of upper and lower limits for each measurement eliminates problems encountered by technicians in deciding whether equipment is operating satisfactorily.

3. It provides a permanent record for use in trend analysis. Recently, efforts toward reduction of maintenance costs have turned to the problem of predicting malfunctions to avoid time lost in troubleshooting catastrophic failures. A record of each measurement at each test point, sampled periodically, provides a means for accurately observing component deterioration.

4. It reduces skill and manpower requirements. By turning the routine tasks of the technician over to the machine, fewer technicians are required. Automation through the use of the tape programer enables relatively unskilled operators to conduct routine production line inspections or complex weapon system preventive maintenance checks.

5. It can perform programed self-tests to measure its own performance capability prior to weapon system checkout.

The human engineering effort had as a specific aim the exploitation of the aforementioned advantages, as well as the usual goal of applying human engineering principles to the design. The programer-comparator development was a modification of a previously existing model of checkout equipment. Many of the functional and structural characteristics of the previous model were carried over, with minor changes, to the new design. Among these were the control panel design and the general operating procedure.

Figure 1, showing the original control/display panel layout, illustrates the design at the time human engineering entered the picture. The operating area consists of three panels. The top panel is reserved for visual displays and contains two types of indicators: several simple transilluminated indicators; and rectangular alphanumeric display units, on which can be projected numbers, short words, and symbols. The alphanumeric lights indicate test indentification number, type of measurement, measurement value, and measurement range. The simple indicator lights indicate equipment status, status of the test in progress, and qualitative test results. Note that the cross-hatched areas on either side of this panel indicate unusable portions of the panel. Several equipment units are mounted against the inside of the panel at those points.

The central panel contains operating controls for starting and stopping the programer-comparator, as well as a single indicator to show that the equipment is ready to operate.

The bottom panel contains a keyboard for manual programing, accessory operating controls, and a number of very tiny indicator lights, used primarily for trouble-*shooting*. This panel area is intended to support maintenance functions. The entire bottom panel is recessed into the cabinet and covered by a hinged door.

It is obvious that the designer of these panels did not altogether ignore basic human engineering principles. An effort was made to separate maintenance and operating functions. Moreover, the majority of visual indicators are located on the upper portion of the panel, while controls are on the lower portion.

A functional analysis was conducted by the Human Engineering Unit to establish human performance requirements and tasks for the equipment. The analysis indicated that the programer-comparator is used for two distinct operations: checkout and diagnosis. During checkout operations, the weapon system performs a programed series of tests and measurements on a weapon system or on itself. During diagnosis operations, which begin when a malfunction, maladjustment, or other improper operations, of the weapon system or checkout equipment is detected, the equipment provides information which can be used to diagnose and correct the discrepant condition.

Since the checkout phase is essentially automatic, only a small amount of information is required by the operator monitoring the checkout. The diagnostic phase, on the other hand, involves complex troubleshooting and problem-solving procedures and requires a large amount of information. Consequently, most of the indicators provided with the programer-comparator are for use during diagnosis of weapon system or programer-comparator malfunctions, or for other maintenance activities such as calibration of the weapon system.

Additional information about the operation of the programer-comparator was obtained by observing the use of an earlier model checkout device using approximately the same control/display layout. The analysis and observations led to a definition of specific problems. Among the major problems were these:

1. The original panel design, while providing for separation of checkout and diagnostic functions, actually mixed controls and displays used during each phase. Since all indicators are used during the diagnostic phase, placing various indicators on separate panels is unnecessary and at times confusing. In addition, the rudimentary

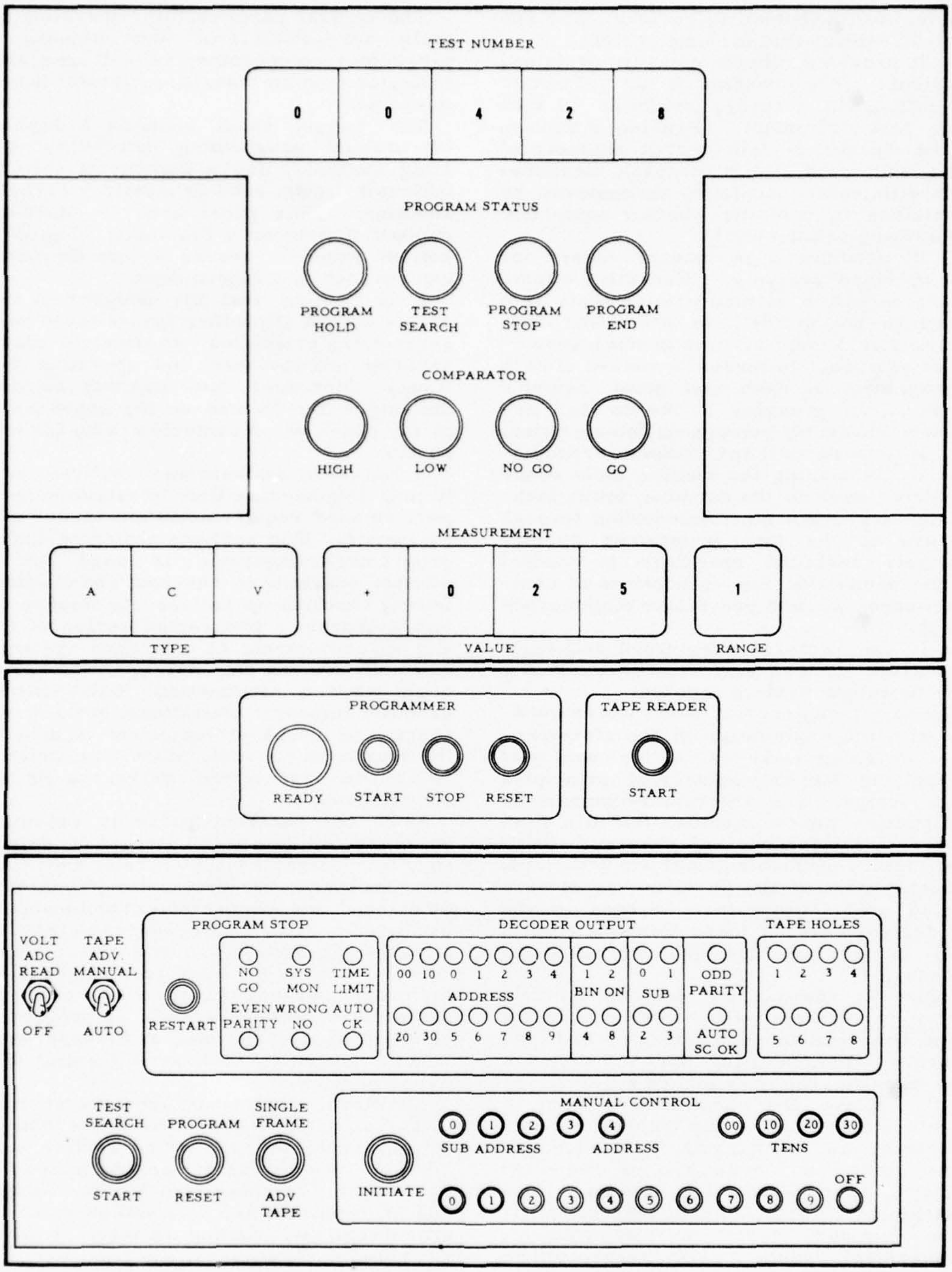

Figure 1. Original Control Display Layout.

effort made in the original design to place indicators on the upper panel and controls on the lower conflicted with a functional arrangement.

2. Recessing and covering the maintenance panel served no useful purpose. Observations of operators using the earlier model showed that the door was never closed during operation and rarely closed when the equipment was idle. Recessing the panel also added to the difficulty of seeing maintenance lights and operating controls.

3. Insufficient information was presented to the operator by the status indicators. In particular, several test conditions had to be recognized by the sounds made by the tape reader.

4. Provision was not made for interlocking several of the controls to prevent damage or loss of test time due to inadvertent or improper operation.

5. Provision was not made for testing lamps in the alphanumeric displays. The displays contain over one hundred incandescent bulbs.

6. Several of the components were poorly adapted for use with the equipment. For example, the tiny maintenance lights were inadequate, particularly because improper orientation of the bulb behind the panel would present a dead spot to the operator, making it extremely difficult to tell if the bulb was illuminated. Another component, the keyboard, was extremely awkward to use and likely to cause data entry errors.

Figure 2 shows the recommended control/display panel layout. Time and budget problems precluded incorporating all of the desired features, but considerable improvement was made over the original design. The changes included the following:

1. Allocation of all visual indicators to the upper panel and all controls to the lower panel.

2. Separation of checkout and diagnostic functions by grouping indicators and controls. All of the indicators required for checkout are now located in the lower row of alphanumeric indicator lights.

3. Elimination of the recessed panel.

4. Use of more adequate maintenance lights.

5. Combining tape reader controls on a single mode selector switch.

6. Replacement of the keyboard by three rotary selector switches for entering the three-digit code numbers. A more sophisticated keyboard was rejected as too expensive for the particular programer-comparator application under consideration.

7. Incorporation of a rotary selector switch for testing the alphanumeric projection lamps in groups of sixteen.

8. Addition of status designators and incorporation of all status designators into alphanumeric displays.

9. Addition of protective interlocks for critical controls.

10. Provision of a key-lock switch for manual programing controls to protect the weapon system from inexperienced personnel, particularly when checkout is assigned to a semiskilled or unskilled operator.

An engineering model of the programer-comparator was built and all of the recommended changes shown here, as well as others relating to other parts of the equipment, were incorporated into the design. Later developments, in line with product improvement efforts, enabled the Human Engineering Unit to recommend further changes.

Figure 3 shows additional changes recommended for the programer-comparator. Briefly, they include a slide-out keyboard with built-in alphanumeric display, complete separation of checkout and diagnostic controls, and conversion of many of the maintenance lights to alphanumeric display units. This design was also accepted by the project engineers.

The main point to all of this is that human engineering recommendations are accepted by equipment designers and are incorporated into equipment design. Also, considerable product improvement can be accomplished when human factors requirements are satisfied by equipment design.

Although the task just described had a satisfactory solution, it was not accomplished without problems. Some of those problems should be of interest to this audience because they bear directly on the relationship between industry and the military. Although the problems are typical of industrial environment, they are not usually brought out in formal discussions of human engineering.

Many factors, including military needs, have led to shorter and shorter lead times for design. This reflects on the quality of human engineering in the sense that formal human engineering techniques involving research, data collection and analysis, simulation, and the like, cannot be used, because of their time requirements. This oftentimes leads the human engineer to make off-the-cuff recommendations based on experience, remembered data, and plain commonsense.

A partial remedy to this problem would be for military organizations to provide industrial engineers with more adequate and effective design standards. Some standards already exist for example, the Air Force's MIL-STD-803. Those standards that exist, however, suffer from two major deficiencies. One is incompleteness; many useful human engineering principles are not specified.

The second deficiency is the lack of data about the conditions under which the standards apply. Whenever a standard is specified, the range of applicability of the standard

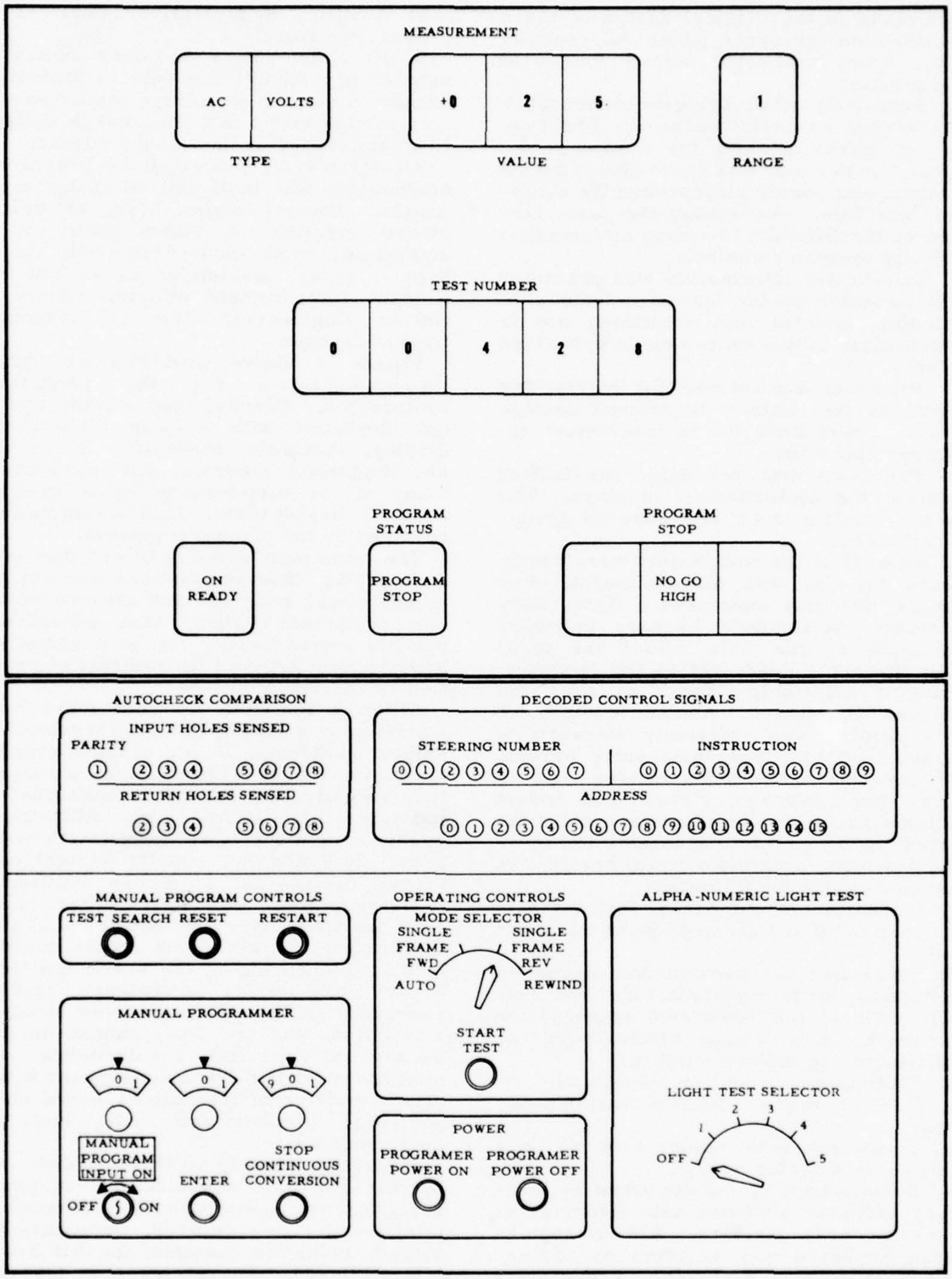

Figure 2. Recommended Panel Design.

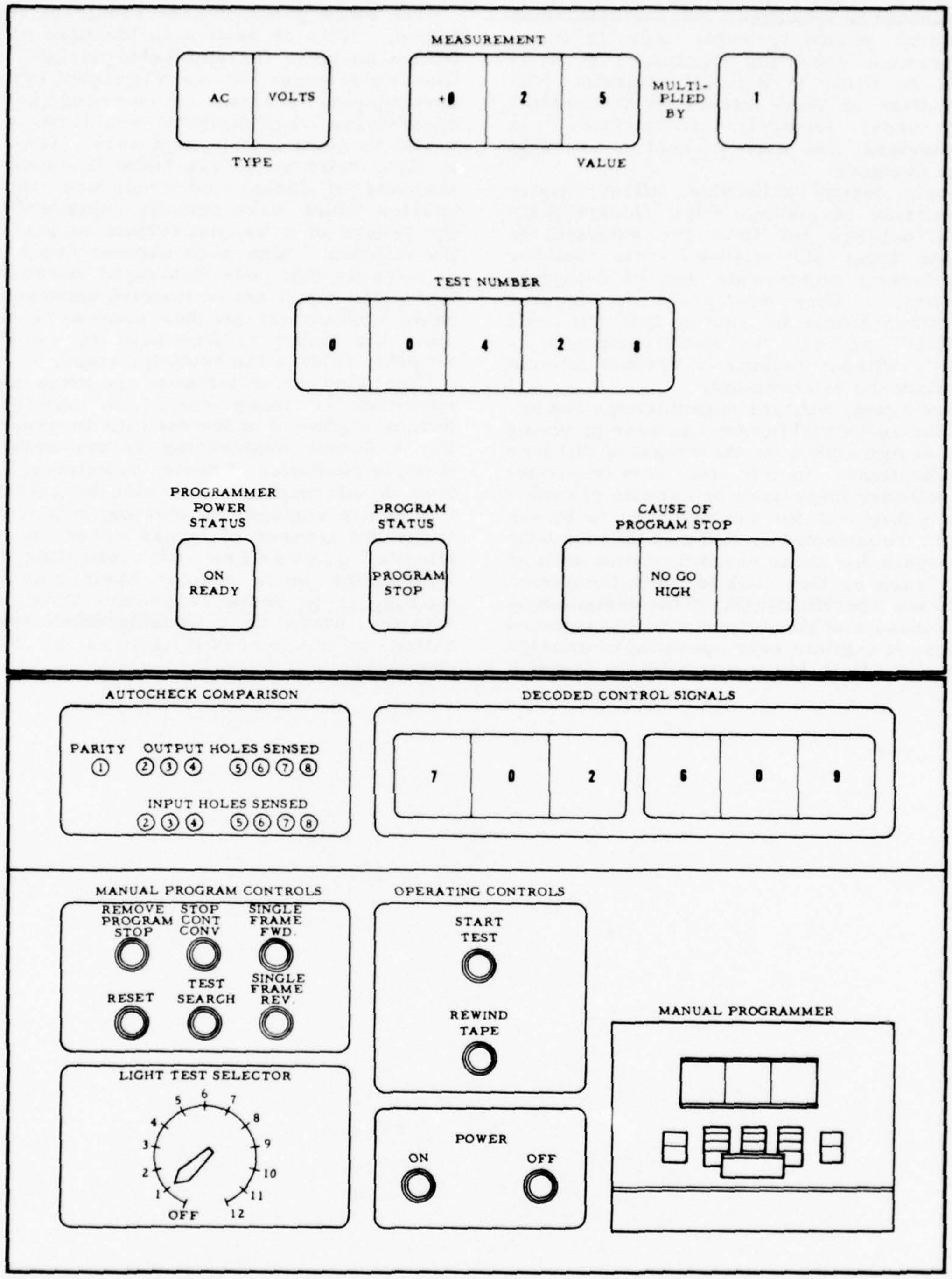

Figure 3. Improved Panel Design.

also should be specified. For example, some standards obviously apply only to time-compressed operating conditions such as might be found in aircraft controls. The application of those standards to controls used under leisurely circumstances is meaningless and may present a hardship to the designer.

Short design schedules affect human engineering in another way. Design engineers pressed for time are reluctant to deviate from old tried-and-true methods of selecting components and of designing circuitry. They are prone to dismiss recommendations by saying that "it can't be done" or that "no such component is made", without making a serious attempt to satisfy the requirement.

Here again, military organizations can assist the industrial human engineer by giving their design standards the weight of military specifications. In this line, it is important that military inspectors be capable of evaluating equipment for conformance to human factors requirements, and that they actually do inspect for those characteristics with as much care as they look for deviations from hardware specifications. If the design engineer knows that his equipment will be rejected because it exhibits poor operating or maintenance qualities, his cooperation is assured.

One other problem area should be mentioned. This is related to the need of the human engineer for applicable design data. The experiences of each weapon system development program in meeting human engineering requirements would be very useful to other human engineers. The kind of data referred to are found in anecdotal accounts of design and procedural inadequacies which have actually contributed to the failure of a weapon system to perform its mission. One such account concerned a missile that was destroyed because a technician could not distinguish between two cable connectors; another involved a missile that failed to fire because someone forgot to release the holding clamps.

This kind of information is much more effective, in many cases, in convincing design engineers of the need for incorporating a human engineering recommendation than the recitation of design principles. This kind of information would also be useful to the human engineer in alerting him to unsuspected sources of human error. A systematic procedure for collecting this information on a regular basis and forwarding it to human engineers throughout industry would be a considerable contribution to the effectiveness of these engineers.

CHAPTER 4
U. S. ARMY QUARTERMASTER CORPS PRESENTATIONS

A. RELATION BETWEEN PHYSICAL AND SUBJECTIVE PROPERTIES OF ODORANTS: Howard G. Schutz; Battelle Memorial Institute, Columbus, Ohio

B. THE ABILITY OF HELMETS TO ATTENUATE SOUND: Alexander Cohen, Ph.D.; U. S. Army Quartermaster Research and Engineering Command, Natick, Mass.

C. PROGRESS REPORT ON AVERT: Captain Jozef F. Senna, QMC; U.S. Army Quartermaster Research and Engineering Command, Natick, Mass.

A. RELATION BETWEEN PHYSICAL AND SUBJECTIVE PROPERTIES OF ODORANTS, by Howard G. Schutz, Battelle Memorial Institute, Columbus, Ohio

INTRODUCTION

In developing food rations for the Armed Forces, the Quartermaster Food and Container Institute is responsible for providing rations that can be stored under extreme conditions of time and temperature and still remain palatable. Palatability, or the more inclusive term "food acceptance", is determined by a number of interacting factors operating within and on the individual, including flavor, previous attitudes, and physiological conditions. Of these factors, flavor is the one that can be most readily modified and thus has received the most attention by workers in the area of ration development.

Flavor is a complex perception that is ordinarily considered to be made up of the following components: taste, odor, feel, kinesthetic sense, and, to a lesser degree, color and audition. Of these factors, it is generally agreed that taste and odor are the major contributors. Research in the area of taste has progressed reasonably well, as knowledge of the basic tastes and their adequate stimuli have been known for some time. In the area of odor, however, progress has been disappointing, because of the lack of information on the nature of the stimulation of the olfactory sense and of a basic classification of odorants.

The Food Acceptance Branch of the Quartermaster Food and Container Institute has recognized that research in the area of correlating subjective responses to odorants and physical properties of these odorants would contribute to the development of an odor-classification system. Such a system would provide better control for the odor component of flavor. Therefore, the Food Acceptance Branch decided upon a research program, and Battelle was awarded a contract to conduct studies on this problem. Since this was an interdisciplinary problem, a research team consisting of psychologists and chemists was assigned to this program.

Before the specific research program that Battelle is conducting is described, it would be well to consider some of the basic problems in odor research. Numerous attempts have been made to explain why some materials have a strong smell while others have a weak odor or none at all. Explanations have been given on the basis of many different physical characteristics of materials. None of these explanations has proved satisfactory.

Some of the suggested physical properties include structure, reactivity, infrared and ultraviolet spectra, solubility, and absorption characteristics.

The failure of any one of these properties to account for all odor phenomena is not surprising, considering what is known of the complexity of other biological systems. In addition, work in the area of olfaction is plagued with such problems as adequate control of the odor stimulus, purity of chemicals, psychophysical method by which odors are studied, individual differences in odor behavior, and lack of knowledge about the olfactory epithelium. All of these factors have helped deter the accumulation of valid generalizations about the basic dimensions of odors and the nature of odor reception. The present investigators believed that a model based on the combination of several physical properties would be necessary in order to understand odor dimensions better. It was toward the demonstration of this method as a feasible one that the research efforts in the present program were directed.

OBJECTIVE

The goal of this research program is to attempt to relate physical properties of compounds to subjective or psychological properties and to use this information to help understand the olfactory process and to develop a classification system for odorants.

PROCEDURE

The research program was divided into three phases: (1) the selection of odorants and collection of physical data, (2) the collection of subjective data, and (3) relating the physical to the subjective data.

Phase 1

Thirty odorants were selected for study on the basis of being representative of many types of odors. All were pure chemicals. They are listed in TABLE I. This group contains both pleasant and unpleasant, and weak and strong odors, as well as one homologous series of alcohols from methanol to octanol.

The choice of physical data to be collected about these substances was guided by two criteria. First, characteristics were wanted which would be readily available from the literature or from simple experimental procedures. Secondly, physical properties were wanted which have been suggested at one time or another to be important to the olfactory process. Eighteen properties were finally selected for inclusion in the study and are listed in TABLE II. The values for most of the properties were obtained from the literature. Hemolytic activity, UV, infrared, and absorption properties were determined at Battelle.

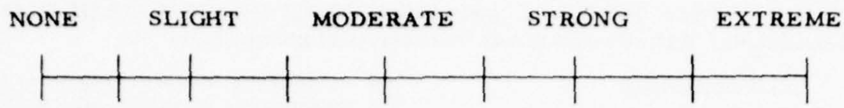

Figure 1. Intensity Rating Scale

for a period of time from the initial rating to a point at which the intensity ratings remained essentially constant. These values are shown in the second column of Table III.

The third measure of intensity was the absolute threshold. This is the lowest concentration of a substance which can be reliably detected by an observer. The values for this measure were collected from the literature and expressed in the common unit of molecules per cubic centimeter of air. It was possible to find values for only 19 of the 30 substances. These are shown in the third column of Table III.

For the second type of sensation, the qualitative character of a substance, an experiment was conducted at the Quartermaster Food and Container Institute in which 20 people rated the 30 odorants in terms of 27 qualitative attributes as well as on the basis of preference and intensity. The rating scale was the same as was shown in Figure 1. The attributes were selected from among the many terms reported in the literature that had been used to describe the way odors smelled. These attributes are listed in Table IV. The average ratings for the 20 people were computed and each of the 30 odorants was correlated with every other odorant. These yielded a matrix of correlations which indicated the extent to which the odorants smelled alike, that is, the degree to which people rated them in a similar way for the 29 attributes.

This matrix of correlations was then subjected to a statistical analysis--factor

TABLE III. SUBJECTIVE DATA ON 30 ODORANTS

Odorants	Supra-threshold Intensity	Rate of Adaptation, scale units/min	Absolute Threshold, molecules/cc
Methanol	5.5	0.900	1.1×10^{16}
1-Menthol	6.8	0.450	2.0×10^{11}
2-Propanol	6.7	0.366	-
p-Dichlorobenzene	5.3	0.420	-
Ethyl acetate	7.2	0.312	5.07×10^{15}
Benzaldehyde	7.0	0.264	1.12×10^{12}
1-Heptanol	5.9	0.174	9.0×10^{11}
Iso-safrole	5.5	0.378	-
1-Pentanol	5.7	0.360	6.8×10^{12}
Skatole	6.4	0.300	1.8×10^{9}
1-Hexanol	6.8	0.384	6.72×10^{12}
Eugenol	6.2	0.360	-
Vanillin	4.3	0.180	4.5×10^{6}
Pyridine	8.1	0.336	3.1×10^{11}
Ethyl sulphide	6.6	0.438	7.48×10^{10}
Methyl salicylate	5.1	0.198	4.27×10^{14}
Guaiacol	6.2	0.300	-
Amyl acetate	6.3	0.342	1.82×10^{14}
Butylamine	7.9	0.534	-
1-Butanol	6.6	0.336	8.2×10^{12}
Butyric acid	6.9	0.360	1.4×10^{11}
Methyl ethyl ketone	8.0	0.708	-
Benzyl acetate	5.3	0.264	-
2-Picoline	7.8	0.228	-
Coumarin	5.0	0.312	2.1×10^{11}
1-Propanol	6.0	0.432	5.0×10^{13}
1-Octanol	5.6	0.234	3.0×10^{10}
Benzyl benzoate	4.4	0.402	-
Geraniol	5.2	0.360	-
Ethanol	6.0	0.552	2.44×10^{15}

TABLE I. THIRTY COMPOUNDS USED IN ODOR STUDIES

Methanol
1-Menthol
2-Propanol
p-Dichlorobenzene
Ethyl acetate
Benzaldehyde
Iso-safrole
1-Pentanol
Skatole
1-Hexanol
Eugenol
Vanillin
Pyridine
Diethyl sulphide
Methyl salicylate
Guaiacol
Amyl acetate
Butylamine
1-Butanol
Butyric acid
Methyl ethyl ketone
Benzyl acetate
2-Picoline
Coumarin
1-Propanol
1-Octanol
Benzyl benzoate
Geraniol
Ethanol

TABLE II. 18 PHYSICAL PROPERTIES CHOSEN FOR ODOR CORRELATION STUDIES

Hemolytic activity
Vapor pressure
Surface tension
Ultraviolet absorption, 200 to 400 millimicrons
Charcoal adsorption
Alumina adsorption
Silica gel adsorption
Fuller's earth adsorption
Lecithin adsorption
Infrared absorption, 3.0 to 6.5 microns
Infrared absorption, 7.0 to 10.5 microns
Infrared absorption, 11.0 to 14.5 microns
Boiling point
Solubility in water
Heat of combustion
Index of refraction
Density
Molecular weight

Two of the more unfamiliar properties will be described. Hemolytic activity is the extent to which a substance accelerates the breakdown of red blood cells. This property has been suggested as being related to the manner in which a substance penetrates the olfactory receptor.

Adsorption is not itself unique but the method of measurement used here is a combination of physical and psychological techniques. Each of the 30 materials was percolated through glass columns containing the adsorbing substance. The time required before the odor could be detected above the column was used as a measure of adsorbing tendency for each substance.

Phase II

The data collected on subjective properties were drawn from two sources: values obtained from the odor literature, and experimental studies conducted at Battelle or at the Quartermaster Food and Container Institute.

There are at least two basic subjective attributes of all senses; one is the intensity of a sensation and the other is the qualitative character of a sensation. For example, one might smell pyridine and think it has a strong odor and also characterize it as smelling putrid, while vanilla would probably be considered weak and smell "sweet-like". Both types of sensations are of interest. For the first type of intensity, three related measures were chosen. The first was suprathreshold intensity, that is, the judged intensity of a substance when it is smelled in its pure form. For this measure, data were used which were collected at Battelle by having people rate the degree of intensity of a substance on a 9-point rating scale from 1, no intensity, to 9, extreme intensity, as shown in FIGURE 1. These values averaged over 10 people are given in the first column of TABLE III.

The second measure related to intensity was rate of adaptation, also determined at Battelle. Adaptation in olfaction is the property of an odorous substance to smell less intense when an individual has been exposed to it for a period of time. This property was measured by having people rate the intensity (with the same scale as described above) of each of the 30 odorants over a 10-minute period, during which time they smelled the odorant every 30 seconds. The results for 10 people were averaged for the 20 rating points obtained in the 10-minute adaptation period. A check on the reliability of the measurements was made by having some people rate the odors a second time. Naturally they were not aware that they were repeating their judgments about an odor. Figure 2 illustrates graphically the high reliability obtained for one substance, butylamine, as well as methyl salicylate, which has a distinctly different curve.

A method for representing rate of adaptation was adopted, which consisted of the change in scale units of intensity per minute

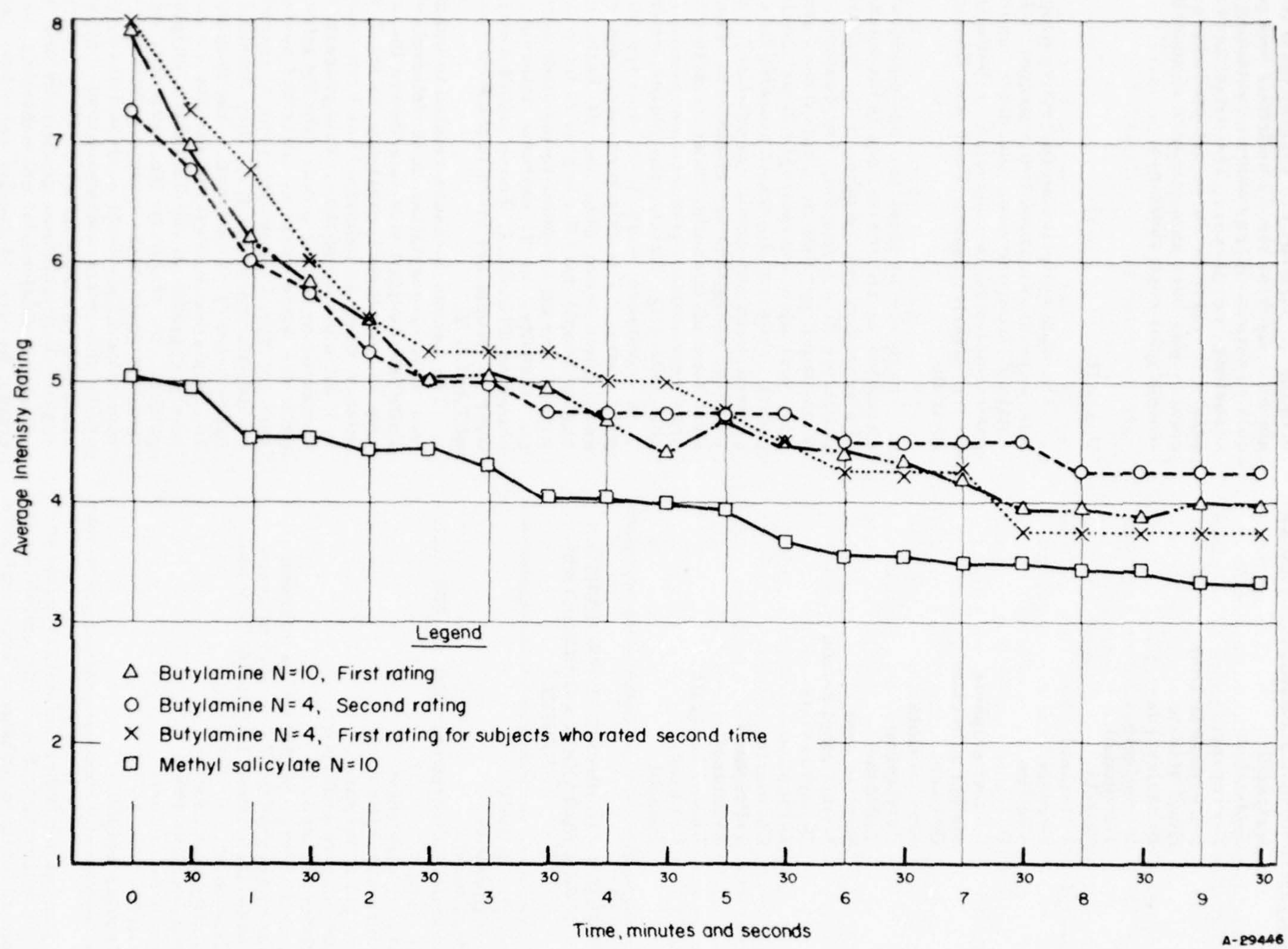

Figure 2. Adaptation Curves Illustrating Reliability and Differences in Rates of Adaptation

analysis--which has as its aim the determination of the smallest number of independent dimensions or factors that represent a larger number of variables. In the case of these odorants, the problem was to determine the smallest number of groupings of odorants that represented groups of similar smelling materials. From this analysis 9 factors were extracted. Each odorant has a given degree of relation or weighting for each factor. Table V gives the 9 factors and the three chemicals which were weighted highest on each of the factors. Thus, each of these groups of 3 chemicals have a similar characteristic of smell which makes them alike. To give the factors names in terms of the 29 attributes on which they were rated, the high rating attributes were examined for each group of 3 chemicals. From this information, tentative names have been given the factors. The naming of some of the factors was relatively easy while others are little more than educated guesses. The names given the factors are also shown in Table V.

Phases I and II provided the basic material for determining the relation between physical and subjective properties of odorants: the values for the 30 odorants in terms of the 18 physical variables and the 12 psychological variables.

TABLE IV. 29 SENSORY ATTRIBUTES ON WHICH ODORANTS WERE RATED

sulfurous
goaty
oily
smoky
spicy
cool
fishy
medicinal
dry
burnt
flowery
garlicky
fragrant
woody
pungent
warm
musty
sweet
sour
etherish
putrid
heavy
tarry
fruity
acrid
metallic
rancid
preference
intensity

Phase III

Phase III consisted of relating these two sets of data. The first step in this process was to compute the correlations between all possible pairs of physical variables, between all possible pairs of physical and psychological variables, and between all possible pairs of psychological variables. These correlations are displayed in Table VI.

A point of discussion about correlation may be in order. Correlation is a statistical technique for determining the degree of relationship between two variables. This statistic, labelled $\underline{r}$, can range from -1.00 to +1.00. A .00 represents no relation while +1.00 represents a perfect positive relation, and -1.00 a perfect negative relation. Values in between indicate varying degrees of relation. Thus +0.80 indicates a high positive relation while +0.40 indicates a moderately positive degree of relation.

Examination of this table reveals some interesting facts. First, many of the physical variables were highly related to one another. Second, the psychological variables were generally unrelated to one another. Third, there were many statistically significant correlations at the 5 per cent level of confidence between physical and psychological properties. A statistically significant r at the 5 per cent level of confidence for these data is about 0.34. This means that the relation found would be greater than zero 95 times out of 100.

The fact that many of the physical variaables were highly correlated led to the decision that a factor analysis be conducted for these variables. Thus, just as with the analysis performed earlier for odorants, the smallest number of independent dimensions were wanted which would describe the data. In this case, physical variables were to be grouped together that vary in the same way over the 30 odorants.

This factor analysis was conducted and five physical factors were found. Table VII gives the weightings on each of the five factors for the 18 physical variables. By examining which physical variables were very high or very low on the 5 factors, they were given tentative names shown at the top of Table VII, hopefully representing basic physical factors. Naturally, these factors are a result of the physical values for the 30 substances which were studied and which might differ to some extent from the factors found for other materials.

The next step was to find out how the 12 psychological variables related to the 5 physical factors. This was done by a statistical technique which weighted each of the 12 psychological variables on the 5 physical factors. These values are given in the lower half of Table VII. These numbers can be

TABLE V. QUALITATIVE FACTORS DETERMINED BY FACTOR ANALYSIS WITH HIGHEST THREE CHEMICALS IN EACH FACTOR

FACTOR A	FACTOR B	FACTOR C
Fragrance	Etherish	Sweet
methyl salicylate	1-propanol	methanol
benzyl acetate	methyl ethyl ketone	1-butanol
iso-safrole	ethanol	vanillin
FACTOR D	**FACTOR E**	**FACTOR F**
Burnt	Rancid	Resinous
guaiacol	butyric acid	heptanol
eugenol	skatole	octanol
skatole	octanol	pentanol
FACTOR G	**FACTOR H**	**FACTOR I**
Sour	Spicy	Goaty
hexanol	benzaldehyde	butyric acid
ethyl acetate	amyl acetate	eugenol
butanol	pyridine	ethyl sulphide

considered as correlations, thus the higher the positive or negative number the more a psychological variable is weighted on a given physical factor. The last column, h^2, represents the percentage variance accounted for by all five physical factors for both the physical and psychological properties. This number can range from .00, or no variance accounted for, to 1.00, or 100 per cent of the variance accounted for.

Consider the first type of sensation--intensity. Examination of the values in Table VII reveals that the measures of intensity are highly related to several of the physical factors. Some physical factors do not seem to be as important for one measure as for another. For example, Factor D, polarity, appears to be important to threshold but not to suprathreshold intensity. For other physical factors there exists an opposite relation to subjective factors. For example, on Factor A, molecular size, high intensity is negatively related--while high threshold, thus low sensitivity, is also negatively related. One might interpret this result to mean that, in general, larger molecular size goes along with low suprathreshold intensity but low threshold. Thus, conclusions about the intensity of odorants drawn from physical data differ considerably, depending on whether one is concerned with suprathreshold or absolute threshold measures. Rate of adaptation in general is not weighted as heavily on the physical factors as are the two other intensity measures. It resembles suprathreshold intensity more than absolute threshold, as might be expected, since it was determined from suprathreshold judgments.

Turning to the qualitative psychological variables, Table VII reveals that some variables are not weighted much at all on the physical factors. These are Factors D, E, G, and H. For the other factors there are a number of high weightings on the factors. These values are sometimes reversed, as in the case of psychological factors A and B on physical factors A, B, and C.

What general conclusions can be drawn from the results of these analyses? First, a word of caution. The studies reported here were conducted for 30 out of the literally hundred of thousands of possible odorants. Considering the psychological variables for suprathreshold intensity and rate of adaptation, a high degree of confidence is possible. However, absolute threshold measurements were taken from the literature and from different experimenters, and with all the problems of control in olfactory experimentation it is possible that different values might be obtained if one experimenter had determined all the thresholds. Some of the qualitative factors are quite clear, but as pointed out earlier, others are not at all definite and would require the inclusion of other odorants high in the weak factors for clarification.

The results, then, taken in the light of the previous qualifications still offer a considerale amount of hope for understanding the process of olfaction and developing a useful classification system. First of all, the results on intensity give clear evidence that

TABLE VI. INTERCORRELATION AMONG PHYSICAL AND PSYCHOLOGICAL VARIABLES

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
Hemolytic activity	X_1		−.62	.30	.32	.26	.50	−.04	−.52	−.23	.04	−.23	−.32	.64	−.78	.83	.40	.39	.78
Vapor pressure	X_2			−.74	−.57	−.26	−.42	−.19	.47	.42	.06	−.27	−.09	−.85	.60	−.77	−.66	−.59	−.81
Surface tension	X_3				.82	.17	.20	−.05	−.14	−.50	−.49	.27	.29	.75	−.42	.61	.77	.79	.70
Ultraviolet absorption, 200 to 400 millimicrons	X_4					.11	.14	−.10	−.08	−.22	−.45	.11	.30	.74	−.52	.54	.90	.85	.70
Charcoal adsorption	X_5						.33	.54	−.13	.05	.07	−.17	−.06	.23	−.12	.30	.20	.03	.24
Alumina adsorption	X_6							.19	−.29	−.33	.00	−.04	−.13	.22	−.33	.54	.34	.15	.38
Silica gel adsorption	X_7								−.11	−.11	.28	−.13	−.03	.08	.04	−.11	−.03	−.18	.00
Fuller's earth adsorption	X_8									.20	−.20	.24	.10	−.33	.16	−.57	−.20	−.03	−.30
Lecithin adsorption	X_9										−.09	−.33	−.28	−.29	.39	−.24	−.59	−.42	−.44
Infrared absorption, 3.0 to 6.5 microns	X_{10}											.06	.18	−.18	.32	−.28	−.47	−.51	−.34
Infrared absorption, 7.0 to 10.5 microns	X_{11}												.32	.16	−.03	−.16	.07	.28	.14
Infrared absorption, 11.0 to 14.5 microns	X_{12}													.20	.15	−.14	.30	.19	.00
Boiling point	X_{13}														−.72	.82	.84	.73	.90
Solubility in water	X_{14}															−.84	−.69	−.58	−.85
Heat of combustion	X_{15}																.80	.60	.92
Index of refraction	X_{16}																	.84	.84
Density	X_{17}																		.80
Molecular weight	X_{18}																		
Intensity	Y_1																		
Rate of adaptation	Y_2																		
Absolute threshold	Y_3																		
Factor A	Y_4																		
Factor B	Y_5																		
Factor C	Y_6																		
Factor D	Y_7																		
Factor E	Y_8																		
Factor F	Y_9																		
Factor G	Y_{10}																		
Factor H	Y_{11}																		
Factor I	Y_{12}																		
	N	24	30	26	30	30	30	30	30	30	28	28	28	30	30	23	26	28	30

		Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}
Hemolytic activity	X_1	−.42	−.30	−.23	.28	−.18	−.16	.29	.22	.02	.34	−.05	−.41
Vapor pressure	X_2	.46	.41	.43	−.42	.42	.04	−.02	−.13	−.23	−.03	−.07	.21
Surface tension	X_3	−.22	−.49	−.22	.35	−.35	−.12	−.11	.05	.32	.12	.34	−.10
Ultraviolet absorption, 200 to 400 millimicrons	X_4	−.31	−.42	−.39	.30	−.51	−.12	.13	.14	.06	−.05	.21	−08
Charcoal adsorption	X_5	−.13	−.30	−.37	−.10	−.24	.16	−.01	.16	.23	−.04	−.08	−.05
Alumina adsorption	X_6	−.14	.06	−.27	.04	−.20	−.20	.26	−.05	.33	.12	.02	−.07
Silica gel adsorption	X_7	.00	.00	−.20	−.07	−.11	.27	−.20	.07	.19	−.10	.08	.03
Fuller's earth adsorption	X_8	.15	.46	.26	−.07	.22	.23	−.12	−.03	−.08	−.26	−.15	.28
Lecithin adsorption	X_9	.32	−.16	−.21	−.48	−.14	.34	.06	.11	−.12	−.08	−.15	−.22
Infrared absorption, 3.0 to 6.5 microns	X_{10}	−.19	.12	.22	−.02	.24	.06	.12	.27	−.09	.01	−.21	.12
Infrared absorption, 7.0 to 10.5 microns	X_{11}	−.32	−.16	.43	.48	.26	.27	.12	−.01	.23	.10	.14	.30
Infrared absorption, 11.0 to 14.5 microns	X_{12}	−.19	−.16	.03	.24	−.21	.22	.06	.11	.21	−.34	.02	.28
Boiling point	X_{13}	−.59	−.48	−.56	.45	−.54	−.06	.17	.30	.12	−.14	−.10	−.19
Solubility in water	X_{14}	.52	.17	.37	−.43	.34	.16	−.03	−.02	−.09	−.09	.09	.10
Heat of combustion	X_{15}	−.24	−.44	−.58	.18	−.46	−.45	.15	.17	.18	.15	.22	−.26
Index of refraction	X_{16}	−.33	−.42	−.51	.28	−.50	−.28	.10	.13	.21	−.01	.19	.04
Density	X_{17}	−.36	−.44	−.30	.40	−.33	−.13	.10	.10	−.01	−.18	.14	.11
Molecular weight	X_{18}	−.54	−.36	−.43	.47	−.50	−.22	.13	.12	.13	−.21	−.01	−.12
Intensity	Y_1		.18	.02	−.62	.18	−.18	−.20	−.03	.02	.17	.44	.13
Rate of adaptation	Y_2			.34	−.02	.40	−.16	−.22	−.11	−.25	−.29	−.11	.11
Absolute threshold	Y_3				.28	.76	.07	−.07	−.46	−.03	.33	.11	.29
Factor A	Y_4					.10	.03	−.04	−.08	−.18	−.21	.06	−.03
Factor B	Y_5						−.07	−.04	−.13	−.26	.29	.21	.14
Factor C	Y_6							−.10	−.05	.08	−.15	−.16	.10
Factor D	Y_7								.20	.02	.11	−.30	−.14
Factor E	Y_8									−.04	−.17	−.14	−.05
Factor F	Y_9										.34	.20	.08
Factor G	Y_{10}											.32	−.11
Factor H	Y_{11}												−.17
Factor I	Y_{12}												
	N	30	30	19	30	30	30	30	30	30	30	30	30

TABLE VII. FACTORS FOR 18 PHYSICAL PROPERTIES AND RELATION BETWEEN PHYSICAL FACTORS AND PSYCHOLOGICAL MEASURES

	A Molecular Size	B Resonance Aromatic	C Resonance Non Aromatic	D Polarity	E Protein Adsorption	h^2
Hemolytic activity	.91	.08	-.12	-.05	.10	.86
Vapor pressure	-.72	-.46	.03	-.17	-.30	.85
Surface tension	.33	.78	.26	.08	.16	.82
Ultraviolet absorption, 200 to 400 millimicrons	.28	.79	.39	.02	-.05	.86
Charcoal adsorption	.29	-.02	.10	.70	-.17	.61
Alumina adsorption	.47	.09	-.01	.27	.08	.31
Silica gel adsorption	.08	-.18	-.04	.69	.08	.52
Fuller's earth adsorption	-.58	.07	.19	.01	.02	.38
Lecithin adsorption	-.24	-.37	.01	-.12	-.44	.40
Infrared absorption, 3.0 to 6.5 microns	.04	-.45	-.47	.12	.19	.48
Infrared absorption, 7.0 to 10.5 microns	-.12	.26	-.05	-.03	.52	.36
Infrared absorption, 11 to 15 microns	-.22	.31	.06	.00	.43	.33
Boiling point	.69	.58	.08	-.01	.13	.84
Solubility in water	-.72	-.40	-.02	.11	.03	.69
Heat of combustion	.89	.39	.08	.01	-.24	1.00
Index of refraction	.47	.78	.25	.12	.00	.91
Density	.33	.79	.29	-.11	.13	.85
Molecular weight	.76	.59	.10	.02	.07	.94
Suprathreshold intensity	-.45	-.21	.22	-.01	-.48	.52
Rate of adaptation	-.34	-.33	-.13	-.15	.08	.27
Absolute threshold	-.46	-.16	-.24	-.30	.55	.69
Factor A - Fragrance	.28	.35	.02	-.22	.64	.66
Factor B - Etherish	-.36	-.32	-.22	-.18	.30	.40
Factor C - Sweet	-.30	-.10	-.02	.24	.15	.18
Factor D - Burnt	.17	.01	-.09	-.07	.09	.05
Factor E - Rancid	.19	.00	-.06	.00	.01	.04
Factor F - Resinous	.09	.16	.02	.41	.29	.29
Factor G - Sour	.12	-.06	-.06	-.09	.06	.03
Factor H - Spicy	-.09	.26	.17	.09	.04	.11
Factor I - Goaty.	-.35	.11	-.01	.13	.47	.37

a large proportion of the variability in the intensity of materials, whether suprathreshold or absolute threshold is used as a measure, can be accounted for by a combination of physical variables. There is also a good indication that the meaning of intensity is definitely dependent on whether threshold or suprathreshold values are involved.

The physical factors involved in intensity are concerned with the characteristics of the odorant molecule, which account for its being concentrated in the area of the olfactory epithelium, absorbed by it, and penetrating and having some particular chemical ability to act on the olfactory receptor. The exact details of this process are yet to be completely delineated, but these results should help to clarify certain points.

As far as the qualitative factors are concerned, the factors themselves are of some interest, since they represent a first approximation of a classification system developed from strictly experimental procedures. What the weightings on the physical factors indicate is that part of what makes an odor smell in a particular way may be a specific combination of physical properties interacting with the olfactory receptor. Or if one subscribes to the theory that there are unique olfactory receptors, then it may be that they are stimulated differently on the basis of particular physical properties of the odorants.

Thus, some definite inroads have been made into the problem of understanding olfaction, but more work is certainly needed. Battelle is currently collecting data on odorants by gas-chromatographic analyses. Using these techniques, attempts are being made to simulate the various adsorption processes of the human nose in an attempt to clarify the role of adsorption in olfaction. The three types of olfactory substances being simulated are the nasal mucosa, the fluid bathing the olfactory receptor, and the receptor material itself. Evidence collected to date indicates that this is a promising approach.

We are hopeful that the next few years will result in a real breakthrough in the understanding of olfaction and the application of this knowledge to the research and development of military notions.

B. THE ABILITY OF HELMETS TO ATTENUATE SOUND, by Alexander Cohen, PhD., U.S. Army Quartermaster R&E Command, Natick, Massachusetts

I. The need for noise protection

One of the basic functions of helmets for armor and aircraft crewmen is to furnish noise protection. Such protection is necessary since the noise levels generated by combat vehicles and aircraft are potentially hazardous to operating personnel. Indeed, without some safeguards, these noise conditions may cause:

(1) losses in hearing, both temporary and permanent (11, 12)

(2) disruption in communications (6, 7)

(3) interference with vision, touch, and coordination (11)

(4) fatigue (11, 12)

(5) impairments in alertness and surveillance type behavior (5, 15)

(6) difficulty in problem solving (14, 16)

Obviously, any or all of these effects will reduce the efficiency of personnel in combat situations. Incidentally, the mounting cost of compensation for service-incurred hearing loss to veterans (40 million dollars a year at present (1) and the presence of severe hearing losses in current armor (2) and aircraft personnel (13) testify, in part, to the significance of the noise problem. My aim in this paper is to review some basic noise suppression problems which are common to both combat vehicle and aircraft crewmen helmets, and to indicate possibilities for resolving them. Major emphasis in this presentation will be given to helmets for armor personnel.

II. Description of headgear

Figure 1 shows different views of a helmet now in development. It is designed for armor crewmen and is intended, in part, to provide for noise suppression. With only few exceptions, the basic features of this item exemplify those found in other armor and aircraft crewmen helmets. The helmet shell of this particular item is constructed of ballistic resistant material. The inside surface of the shell is also covered with a liner having crash protective properties. The helmet is held on the head by a sling-type suspension system consisting of three adjustable web straps and a sweat- and neck-band. Further stability is given by the doughnut-shaped, wool-covered earpads of the integral communications kit. These earpads house a set of earphones and are held snugly against the ears by sponge rubber spacers (not shown in Figure 1) between the earpads and the helmet shell. Other components of the communications gear include a boom-suspended microphone, a 3-position selector switch for receiving or transmitting information through radio and/or inter-phone systems, a quick-disconnect line cord with collar clip.

III. Sound attenuation of helmets

The ability of a helmet to give noise protection is reflected by its sound attenuation properties. In general, the greater the

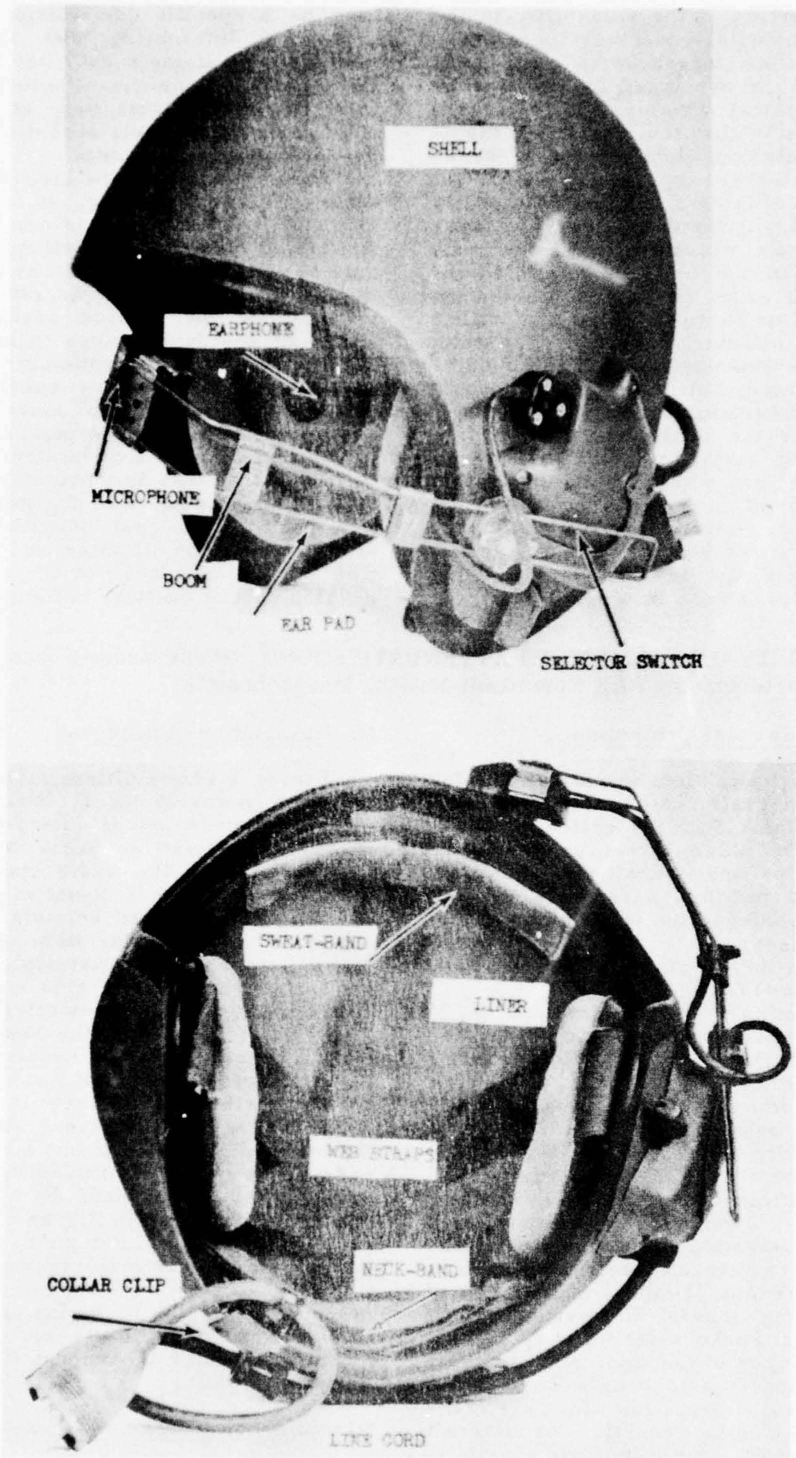

Figure 1. Two Views of Armor Crewman's Helmet

overall attenuation afforded by a headgear item, the greater the amount of noise protection provided by that item to the wearer. Sound attenuation is typically measured by the threshold-shift procedure (3). In this technique, the minimum audible intensity for different frequency sounds is determined for a listener when bareheaded and then redetermined for the same listener when wearing the item under study. Differences between the threshold intensities obtained with and without the headgear being worn, are expressed in decibel units and indicate the extent of the item's attenuation. The sound attenuation for some existing armor and aircraft crewmen helmets is shown in Figure 2. The horizontal axis (abscissa) indicates the frequency of the test sound and the vertical axis (ordinate) shows sound suppression in decibels which was produced by the headgear at that frequency. Note that all the curves show greater attenuation for high frequency sounds (above 1000 cps) than for low frequency sounds (below 1000 cps). This is characteristic of all types of ear protective devices (earplugs, earpads, helmets or combinations of these items), and serves to highlight one of the main problems in effectively reducing armored vehicle and aircraft noise. Specifically, the more intense components of this noise are below 1000 cps or in that region where ear protection is least efficient (4, 17). These low frequency sounds are characteristically more fatiguing to the ear and can readily mask speech (6, 7). Figure 3 further illustrates this problem. The uppermost curve in this graph represents the average of the highest octave band noise levels found in a number of armored vehicles. The curved broken line represents a suggested tolerance limit (12) above which noise exposure for long periods of time is expected to seriously impair hearing. The noise levels for the specified armored vehicles exceed this tolerance limit at all frequency bands, the low frequency sounds being the greatest transgressors. The plotted points indicate estimates of noise levels reaching the ear when different helmets are worn under such noise conditions. These values have been derived from the sound attenuation curves of these headgear items and have been adjusted to account for 90% of the listener population. As you can see, none of the helmets will reduce the low frequency components of armored vehicle noise to safe or tolerable levels. Figure 4 indicates that similar results occur when the various helmet items are worn in a field of aircraft noise. I should indicate here that prospective increases in the power of armored vehicles and aircraft will probably lead to even higher noise levels. Hence, the amount of noise reaching the ear, despite the use of these helmets, will rise accordingly.

IV. Helmet resonance

The problem of inadequate low frequency attenuation is further accentuated by another property of helmets. In most combat helmets, including those for armor crewmen, an air cavity exists between the crown of the helmet and the wearer's head. This provides clearance for the helmet to cushion the head against impact. The air space also makes it possible to ventilate the head area. At the same time, however, this air cavity has a certain frequency of resonance. This means that in a sound field, the air cavity will reinforce or amplify the level of frequency components corresponding to its resonant frequency. Unfortunately, the air space in helmets has a characteristic low frequency of resonance (about 400 cps). Thus, this resonance effect will serve to offset the amount of attenuation that these helmets can provide against low frequency noise.

V. Compatibility with accessory headwear

Wearing a helmet in combination with a gas mask and hood and/or winter clothing may also create acoustic problems. These items, when worn under the helmet, will break the seals between the ears and the helmet earpieces. This reduces the sound attenuation normally given by the helmet when worn alone. Figure 5 shows the change in attenuation which results when the gas mask and hood are worn under various types of helmets. The effects of using these accessory items, as you can see, vary from helmet to helmet and from test frequency to test frequency. The largest loss in attenuation is about 15 db. The differences between the curves reflect the fact that the earpieces in some helmet assemblies are formed of more pliable materials than in others. The more pliable the earpad, the greater the possibility of retaining a partial seal with the ears, despite the presence of the straps of the mask and the hood fabric.

VI. Hearing ambient sounds

Most of the above remarks have dealt with the noise attenuation requirements of combat vehicle and aircraft crewmen helmets. The sound suppression capabilities of these helmets, however, handicap the wearer under conditions requiring normal hearing. For example, the armor crewman may be outside the vehicle and doing patrol or sentry duty. A pilot may wish to hear the noise of his plane's engines so as to monitor better their performance. Under these conditions, a means of permitting sounds to pass to the ears with minimum attenuation is required.

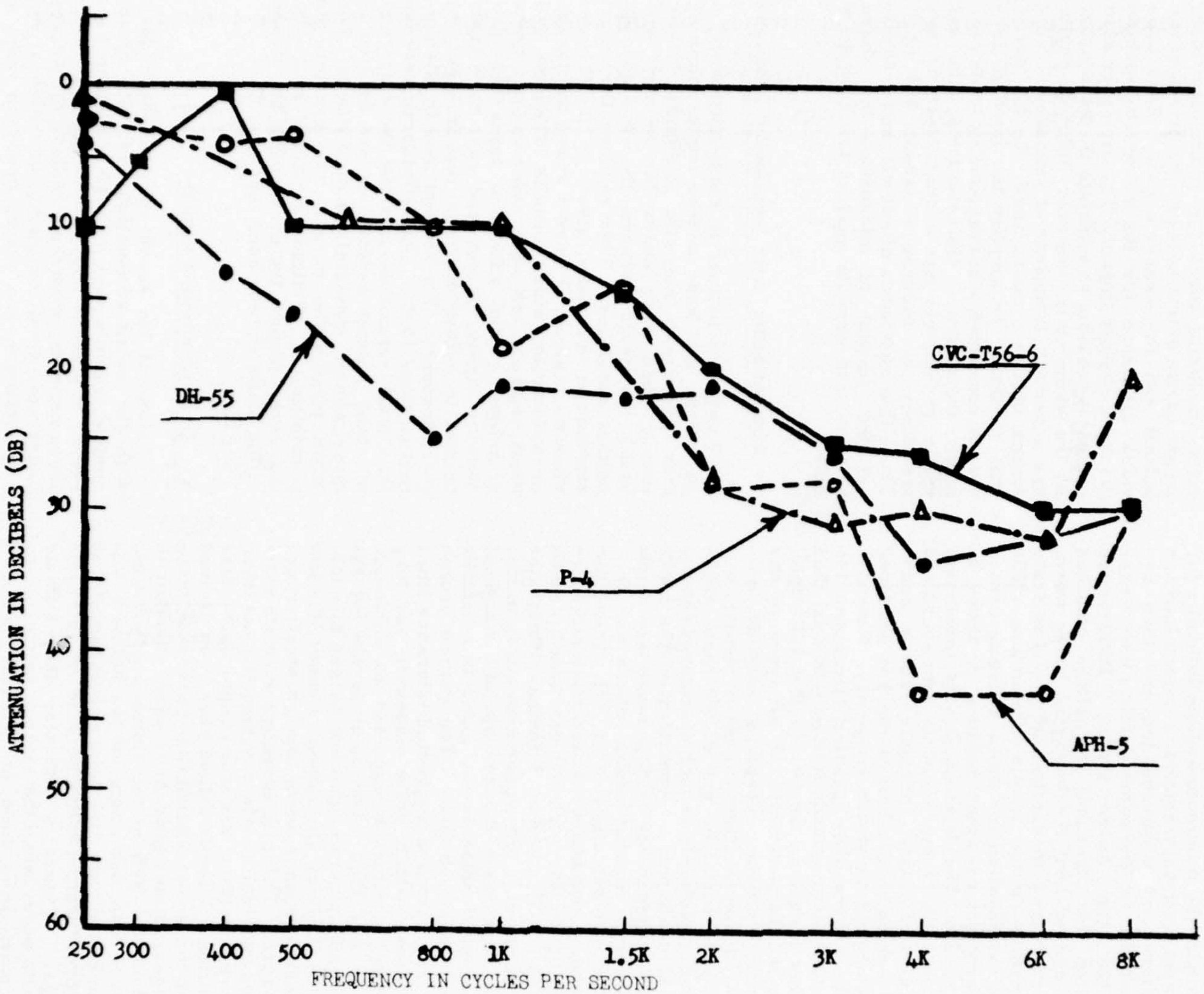

Figure 2. Real Ear Attenuation Data for Some Existing Helmet-Earpad Assemblies

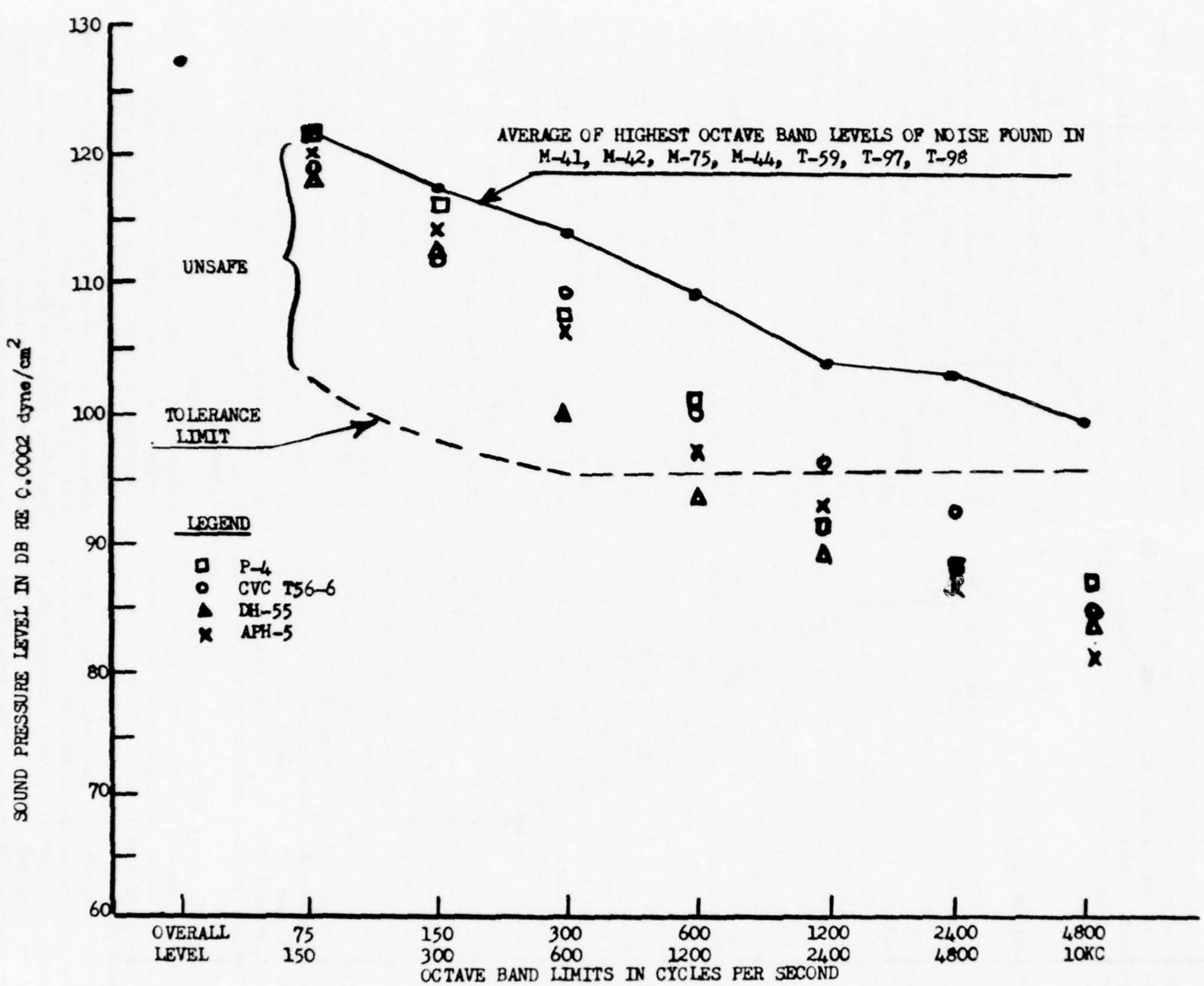

Figure 3. Estimates of Noise at Ear When Wearing Different Helmets in Field of Armor Vehicle Noise

One solution fog the armor crewman would be to wear a non-attenuating helmet, e.g., M-1 steel helmet in the particular situation described above. The pilot could simply take off his helmet. Logistical and safety considerations among others, however, make these remedies appear unfeasible. Perhaps a better technique would be to design some feature into the helmet which would enable the wearer to offset the sound attenuation, depending upon his need to hear ambient sounds.

VII. Possible solutions

Some basic problems regarding the acoustics of helmets have been presented. What are some proposed solutions to these problems?

Firstly, it should be noted that helmets with ideal acoustical features will still provide only limited noise protection. For example, noise may pass into the inner ear via the skull and skeleton of the body and thereby bypass any ear protection device. Some preliminary findings at our laboratory suggest that this type of effect is predominant with weapon-type noise. Based upon temporary losses in hearing following exposures to machine gun-fire noise and continuous noise for comparable durations and equated energy levels, it was found that the use of an armor crewman's helmet gave less protection to the weapon noise than to the continuous noise. Conceivably, the characteristics of weapon noise, i.e., sharp wave fronts of sound caused by sudden rises to high peak intensities, were responsible for these sounds passing through the body while undergoing very little attenuation from the helmet. Regardless, other measures than ear protection devices must be used to cope with the noise problem. One of these should be noise control at the source through the use of noise suppressors or better, engineering noise out of operating equipment. To be sure, the latter approach must come early in the design stages of any piece of hardware. Another possibility is to encapsulate or acoustically shield a man or crew from the noise source.

Along with these control measures, there is room for improving the noise protection given by helmets. Designing the earpieces to inclose a greater volume of air, for example, will help to reduce the passage of low frequency sounds to the ears (8). How large an air inclosure is needed to suppress adequately the low frequency components of armor or aircraft noise, however, is not as yet determined. Workers at the Army Medical Research Laboratory have recently found that activating the acoustic reflex just prior to a burst of weapon noise seemed to give more attenuation to the low frequency components of this noise than conventional ear protective items (9, 10). The acoustic reflex involves contraction of mucles within the ear which, in effect, reduces the amount of sound energy that can pass through the ear. Unfortunately, the use of this principle is restricted to short bursts of noise. Its effectiveness in reducing sustained or continuous noise is questionable.

The principle of noise cancelling also holds promise of improving the suppression of low frequency sounds (18). In theory, this notion consists of superposing noise of equal amplitude but opposite phase upon the undesired ambient noise, the net result of the superposition being zero noise. Tests of this technique with standard communications gear have shown increased suppression for low frequency sounds. Sounds of higher frequency, however, were amplified. One difficulty with the cancellation technique is that it requires rigid performance characteristics in earphones and microphones. Standard communications gear do not possess such features.

The effects of air cavity resonance can be offset, in part, by isolating the helmet earpieces through either independent linkage with the helmet shell or by means of acoustic barriers. Acoustic liners with large surface areas for sound absorption could also be used to reduce the cavity resonance effect. An even better approach to this problem would be to change the resonant frequency through configurational or structural changes of the helmet shell. Perhaps by this method, a resonant frequency could be produced which is less intense in the operational noise field or which is readily attenuated by the earpieces.

The attenuation losses which occur when wearing the helmet in combination with accessory clothing reflect basic incompatibilities between the various items. More pliable earpieces will partially alleviate this problem. What is needed however, is a more integrative approach to headwear design -- one that will incorporate the efforts of the various technical services. A start has been made in this direction with regard to the development of a new helmet for air crewmen.

Various proposals have been considered in solving the problem of hearing ambient sounds while wearing a sound attenuating helmet. One simple technique consists of a string-lever device which, when operated, can break the seal between the ear and one of the helmet earpieces. This enables sound to pass through one ear with minimum attenuation. However, the demand for clearance between the earpad and helmet shell to accomplish an effective break in the seal means that a large and consequently a heavier helmet is needed with this technique. Another solution has been to install ports in

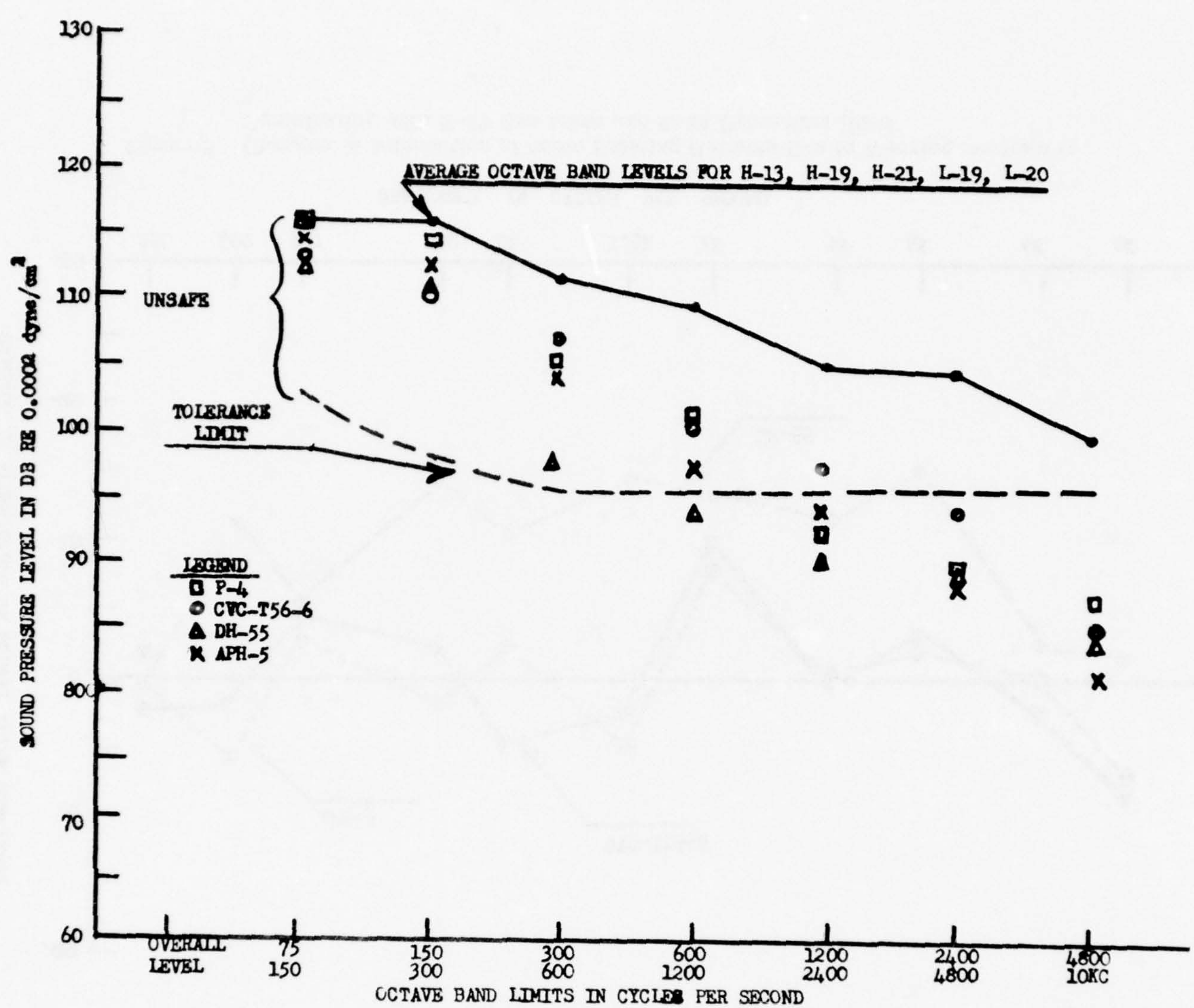

Figure 4. Estimates of Noise at Ear when Wearing Different Helmets in Field of Aircraft Noise

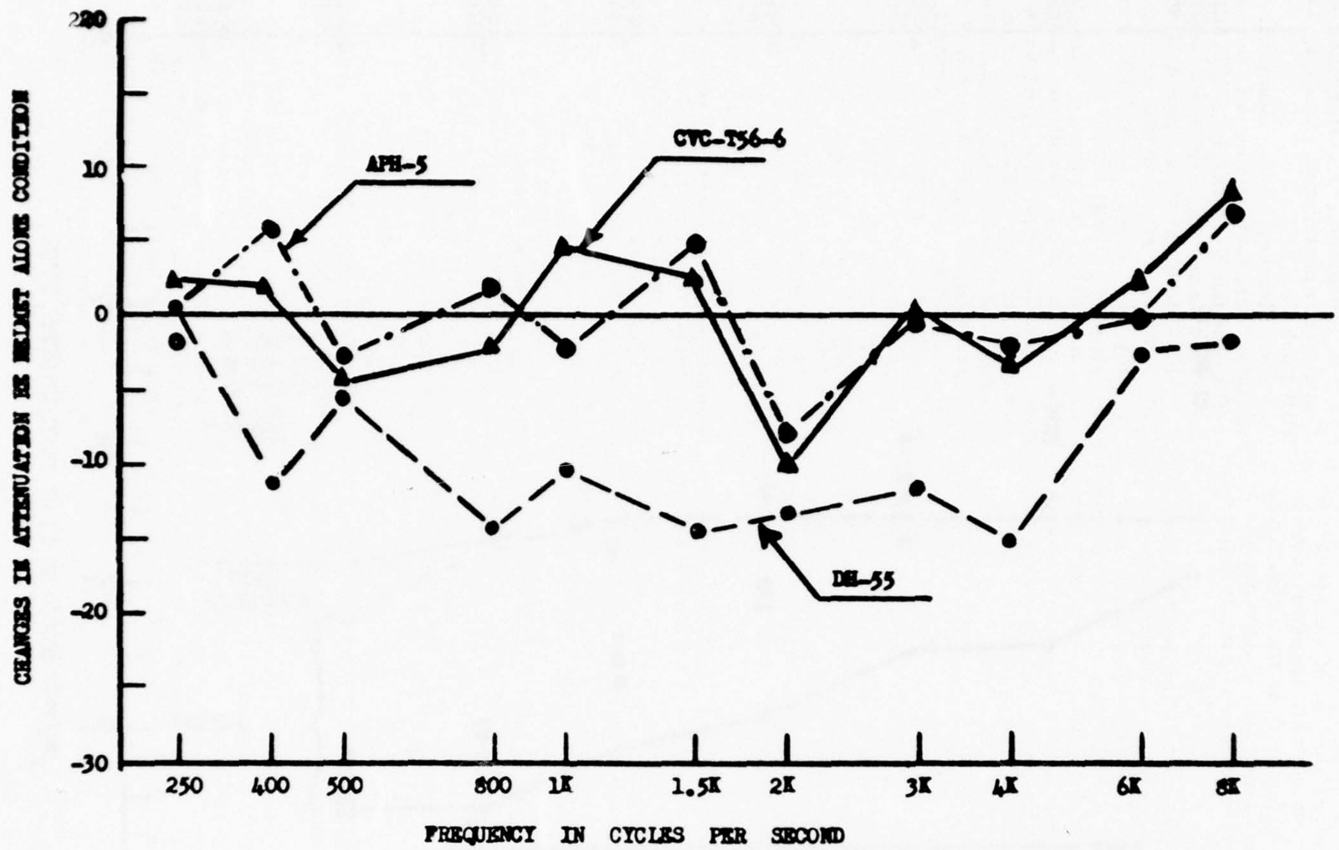

Figure 5. Changes in Attenuation of some Existing Helmets Due to Wearing the Item in Combination with E-75 Gas Mask and E-34 Protective Hood

the earpieces of the helmet, which can be opened or closed, depending upon the wearer's intent to hear ambient noise.

Still another and more sophisticated procedure involves the use of a diaphram in the earpieces which will transmit sounds below a certain intensity to the ears. Once this level is exceeded, the diaphragm hits a stop which impedes further sound transmission to the ears.

Design requirements for helmets, e.g., light in weight, minimum external configuration, provision for ventilation of the head, impose certain restrictions in their giving effective noise protection. With only few compromises, however, the above-mentioned techniques can improve the acoustics of helmets.

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C. PROGRESS REPORT ON AVERT, by Captain Jozef F. Senna, QMC, U.S. Army Quartermaster Research and Engineering Command, Natick, Mass.

The Air Vehicle Environmental Research Team (AVERT) is composed of technical personnel from the Ballistics Research Laboratory of Ordnance, Signal Research Laboratory, Transportation Research Command, Army Aviation Board, Office of the Surgeon General, and Quartermaster Research and Engineering Command. The team obtains its guidance from an Ad Hoc Committee on Armor for Army Aircraft which functions under the auspices of the Transportation Research Command.

This team is primarily oriented toward evaluation of the military environment for air crew personnel manning low performance Army aircraft. Its purpose is the designation of problem areas in this field and the monitoring or conducting of research for their resolution.

As the Armed Forces major user of helicopters, the Army has become greatly interested in the human factors element of this machine and, in turn, AVERT is assisting with the Bio-engineering problems. Since the helicopter is basically an unstable machine aerodynamically and requires the pilot to use all four of his extremities to maintain it in flight, the question has arisen as to the effect of complete or partial loss of an extremity on pilot performance. To assist in determining this, a study is presently being conducted to evaluate means of restricting the movement of an extremity.

The restricting techniques being considered are the application of an electrical stimulus to certain motor nerves, the occlusion of blood flow to an extremity by use of a tourniquet, and weighting of the extremity.

In many of the present helicopters the pilot is seated in a plexiglass dome giving him almost unlimited vision to the front, sides, top and lower front. Though this has certain advantages, it also exposes the operator to vast amounts of radiant energy, thus increasing discomfort because of excess heat which leads to a more rapid onset of fatigue. Another factor relative to this exposed position of air crew personnel is the anxiety or "stress" resulting from lack of protection or shielding from enemy fire when in combat situations. To eliminate or reduce these adverse effects of crew exposure, an investigation has been undertaken to determine if limiting the operator's visual field by enclosing the cockpit area will have any deleterious effect on operator performance.

Another problem being studied is the interaction of aircraft speed, aircraft altitude and target coverage by vegetation (clutter) on an air observer's ability to detect and/or identify ground targets. This study will give indications of the best flight altitudes between 50 and 800 feet and the best flight speed between 75 and 125 mph for certain vegetation characteristics.

Other AVERT studies cover inter-cranial damage during aviation crashes, effects of aviator helmet color on heat transmission, and exposure time of low performance aircraft to ground observation when flying at low altitudes and speeds.

The complete presentation of this subject is classified CONFIDENTIAL; the talk is on file in the Office of the Chief of Research and Development, Department of the Army.

CHAPTER 5
U. S. ARMY MEDICAL SERVICE PRESENTATIONS

A. THE MEASUREMENT OF NOISE OF U.S. ARMY WEAPONS: Dr. Karl D. Kryter; Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts.

B. COMMUNICATION BY ELECTRICAL STIMULATION OF THE SKIN: Captain Glenn R. Hawkes, MSC: U.S. Army Medical Research Laboratory, Ft. Knox, Kentucky

A. THE MEASUREMENT OF NOISES OF U.S. ARMY WEAPONS* by Dr. Karl D. Kryter, Bolt, Beranek, and Newman, Inc.

INTRODUCTION

The measurement of the sound or "noise" from U.S. Army weapons is a project that encompasses several research tasks. These tasks, however, are all directed toward one common goal: the determination of the relation between the measurable characteristics of the sound from weapons and damage to man's auditory system. With this relation established, the Army would have some of the critical information required to specify the operational use of existing weapons and the noise characteristics of new and proposed weapons that will be tolerable to man's hearing.

We wish to note that the measurements and research we are concerned with will give us answers only to the potential damage effect of different weapons; the question of how often a man will be exposed to different noises under operational conditions, and how to balance the preservation of auditory health of Army personnel with tactical military requirements, are research and policy matters beyond the scope of this project.

We have divided the present project into three tasks, as follows:

1. The recording and analysis of the physical characteristics of the noise from U.S. Army weapons.
2. The generation, in the laboratory, of impulse type noise similar to that found for U.S. Army weapons.
3. The measurement of the auditory fatigue (temporary threshold shift) caused by impulse type noise as functions of the rise time, peak amplitude, repetition rate and number of repetitions of the noise.

MEASUREMENT OF THE NOISE FROM U. S. ARMY WEAPONS

The work done on this aspect of the project was presented in a previous report (1). Also, we made for Hesse-Eastern Company some measurements of the LAW weapon (Project 54A).

Briefly, the procedure used in these studies was to record on magnetic tape, with the aid of special microphones and peak level indicators, the sound of the various weapons. The recordings were then analyzed in the laboratory to obtain instantaneous overall peak levels, rise times to peak levels (the time that elapsed from the start of the sound wave to its first peak level), durations, and octave band spectra. The octave band levels were taken as the maximum value reached on an integrator. The integrator had a time constant of .2 second to simulate the general integrative characteristics of the human ear. The results of some of these physical measurements of the noise from weapons are summarized in Table I and Figure 1.

We wish to add, with regard to our physical measurements, that although the instrumentation we used was generally adequate for determining the acoustical spectrum over the range of most direct concern and importance to hearing, from about 100 cps to 10,000 cps, we were not able to record the noise impulse with complete fidelity. The principle problem lies in the fact that the low frequency response of standard magnetic tape recorders cuts off rather sharply below 50 cps or so. Since gun noise contains a great deal of energy at lower frequencies the waveforms we recorded are somewhat deficient from an acoustical point of view. A truer waveform could be obtained by the use of photographic techniques used in conjunction with special methods of analysis or by using magnetic tape recorders that frequency modulate the signal to higher frequencies prior to recording on the magnetic tape. Perhaps some further effort should be expended on obtaining higher fidelity analyses of the noise from selected weapons.

Although much is known about the effects of steady state noise on hearing, little specific information is available as to the relation between the various characteristics of impulsive sounds and hearing, other than it can, and does cause a degree of permanent deafness.

Perhaps the first measure of weapon noise one would look at to estimate its deafening effect would be its peak level measured overall frequencies. However, some measure of the extent to which either an impulsive or steady state sound exceeds the threshold of hearing at each of the audible frequencies is likely to be a better measure for evaluating its potential damage effect than the peak overall level. This is saying, in effect, that it is not the peak level reached by the sound wave when measured overall frequencies simultaneously that is important, but rather it is how this energy is distributed over the frequency scale. The reason, as shown in Fig. 2, is that the ear is more susceptible to damage from some frequencies than from others.

It is interesting to note in this regard that the mathematical analysis of an impulse wave by the Fourier transform reveals that the shorter the rise time, the greater the high frequency content will be in the spectrum. Theoretically, then, we can calculate what the sound spectrum of an impulse noise will be from a knowledge of its peak overall level and

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rise time. This is illustrated in Fig. 3. However, because certain physical characteristics of a weapon and environmental acoustics, such as reverberation in a tank, modify the sound and contribute to its spectral content, it is often useful to determine the spectrum of an impulse sound from a weapon through an analysis performed with filters rather than by mathematical analysis.

Nevertheless, it remains a good rule of thumb that, other things being equal, the noise with the shorter rise time will be potentially the more damaging to hearing. This can be looked upon as due to the presence of more intense high frequency components in regions where the ear is more susceptible to damage. We believe that this is a more constructive way to predict why impulse sounds with short rise times are more damaging to hearing than are sounds with longer rise times than to suggest that the former reach their peak level quicker and are therefore more likely to "break" something in the ear.

Be that as it may, rise time and spectral content are inextricably related to each other but not to peak level. To illustrate, we have rank ordered some of the sounds from Table I according to their level in the octave band 600-1200 cps. (It was in this band that nearly all the weapon noises we measured exceeded the threshold of hearing by the greatest amount.) We also determined the rank order correlations between the level in octave band 600-1200 cps and (1) the instantaneous peak level overall frequencies, and (2) the rise times. The results are shown in Table II.

TABLE II

Comparison of Instantaneous Peak
Exponential Average and Rise Times for Several Contemporary Weapons

	1. Inst. Peak	2. Exponential Aver. .2 sec 600-1200 Band	3. Rise Time
M-1 Rifle	148 db	99 db	.15 millisec
105 MM Ammo Handler	157	111	13.0
30 Cal on T-41A Crew Comp	144	123	.4
76 MM on T-41 Gun Director	167	129	.1
50 Cal on T-41A Gunner	155	130	.1

(Rank Order Correlation) 1 versus 2 = .3

" 2 versus 3 = .68

" 1 versus 3 = .32

$$\rho = 1 - \frac{6 \Sigma d^2}{N(N^2 - 1)}$$

We see in Table II that the relationship (a rank order coefficient of correlation of .3) between peak overall level and the level in octave band 600-1200 cps is quite low, but that the correlation coefficient between rise time and the level in octave band 600-1200 cps is considerably higher, .68.

To summarize, it appears to us that on the basis of present knowledge it is reasonable to evaluate the damage risk to hearing from weapon's noise on the basis of a comparison between an octave band spectrum analysis of the noise and the auditory threshold curve. The noise that exceeds this threshold curve by the greatest amount can be ranked the most dangerous to hearing. This metric, of course, is but one aspect of damage risk exposure. For one thing, the locus of the damage risk on the frequency scale must be taken into account: it is of less practical importance to loss of hearing acuity at some frequencies than at others. In addition, it is necessary to consider the number of rounds of fire a man can be expected to be exposed to over what lengths of time. Unfortunately, data on how impulse noise affects hearing as a function of repetition rate and length of exposure are extremely meager. Until such time as more

TABLE I

Comparison of Characteristics of the Sound from Several Contemporary Army Weapons and the Weapon of Project 54A

The data for the weapons other than Project 54A are taken from the report, "Characteristics of Noise Produced by Several Contemporary Army Weapons," Contract No. DA-49-007 MD-985, Office of the Surgeon General, Department of the Army, Washington, D. C., 6 March 1959.

Gun	Ammo	Position	Inst. Peak	Dura. from Beginning to Peak	Dura. from Peak to End	Total Dura.	600-1200 Band
M-1 Rifle	Armor** Piercing	Ear Nearest Gun	148	.15 milli seconds	55 milli seconds	56 milli seconds	99 db
30 Cal* on M-48E2		Driver's Seat	146	.5 milli seconds	250 milli seconds	250 milli seconds	115 db
30 Cal* on T-41A		Crew Compart.	144	.4 milli seconds	130 milli seconds	130 milli seconds	123 db
50 Cal* on M-48E2		Gunner	147	6 milli seconds	200 milli seconds	206 milli seconds	117 db
50 Cal* on T-41A		Gunner	155	.1 milli seconds	150 milli seconds	150 milli seconds	130 db
76 MM on T-41A	Armor** Piercing	Gun Director	167	.1 milli seconds	500 milli seconds	500 milli seconds	129 db
90 MM on M-48E2	Armor** Piercing	Driver's Compart.	166	25 milli seconds	225 milli seconds	250 milli seconds	126 db
105 MM) on M-52)		Ammo Handler Gun Loader	157 154	13 milli 30 seconds	75 milli 78 seconds	88 milli 108 seconds	111 db 120 db
Proj. 54A		Ear Nearest Gun	171	.05 milli seconds	20 milli seconds	20 milli seconds	130 db

*Values given are for single shots -- for bursts add 2 db to Peak and 600-1200 cps band levels.

**Subtract 4 db from Peak and 600-1200 cps band levels given for "high explosive" ammunition.

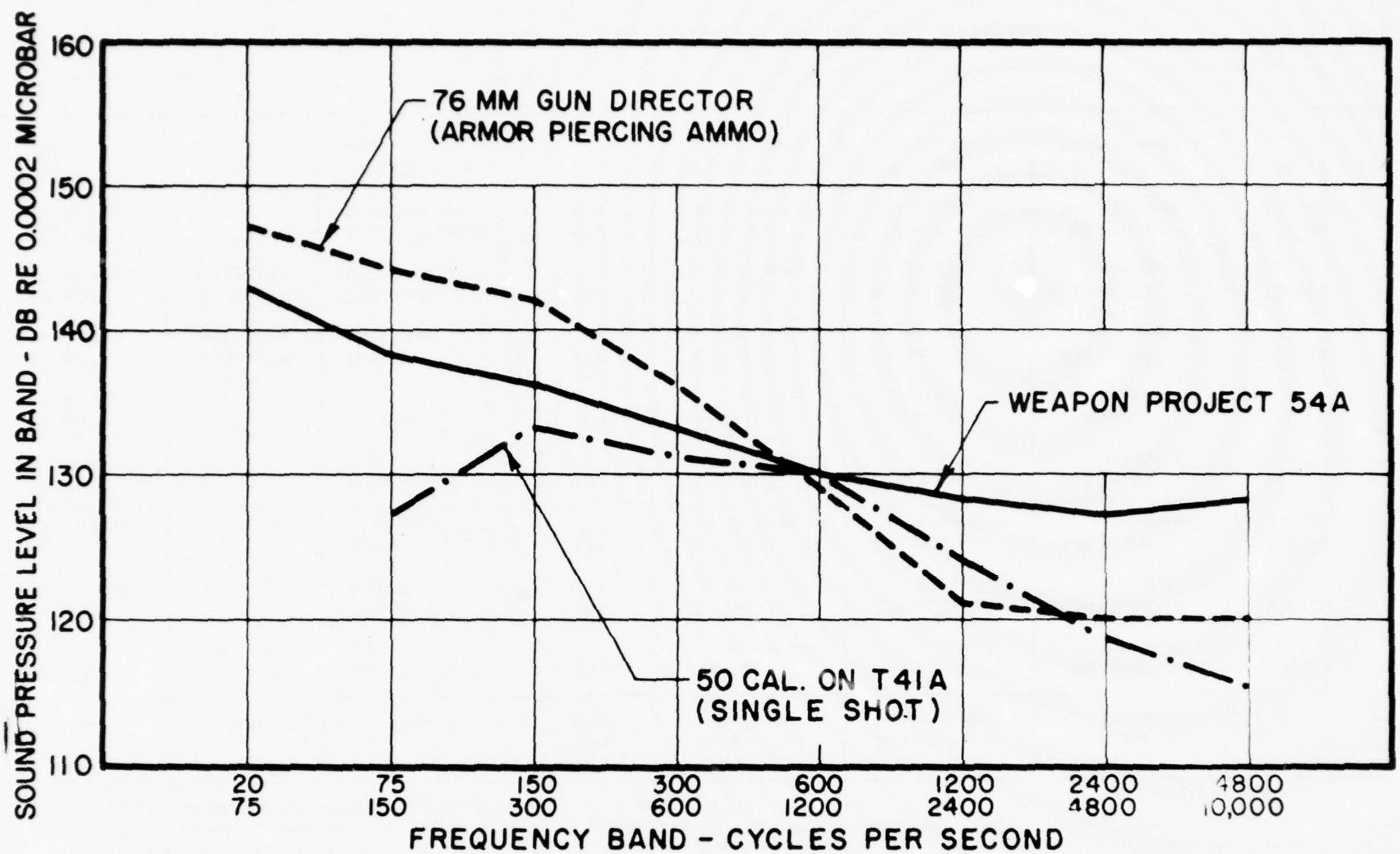

Figure 1. Peak Level of Integrated Sound Pressure (Exponential Average Over 0.2 Second) for Weapon Project 54A and for Two Contemporary Army Weapons.

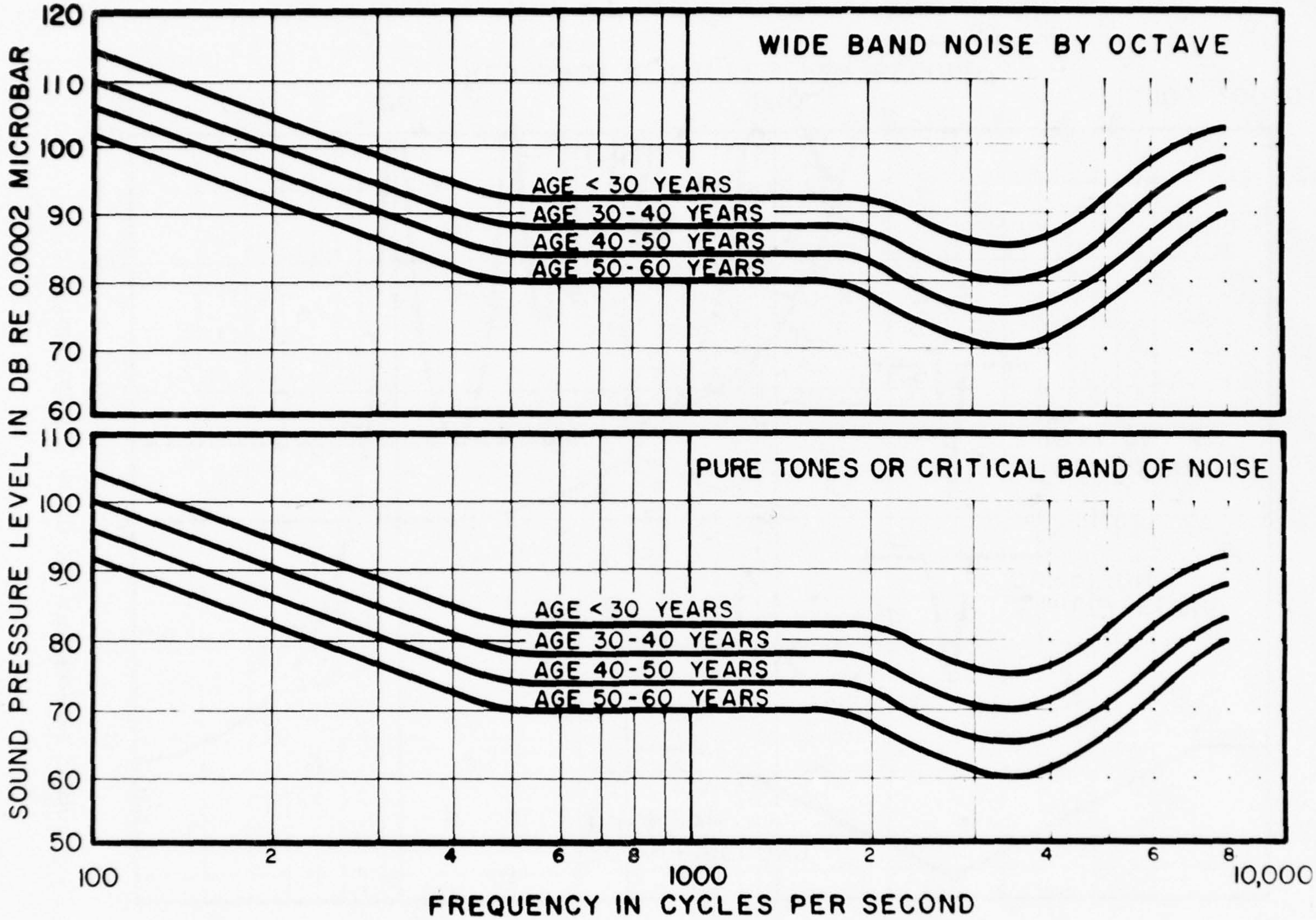

Figure 2. Proposed Damage Risk Criteria for Different Age Groups. These Criteria Are for Steady State, Not Impulsive Sounds.

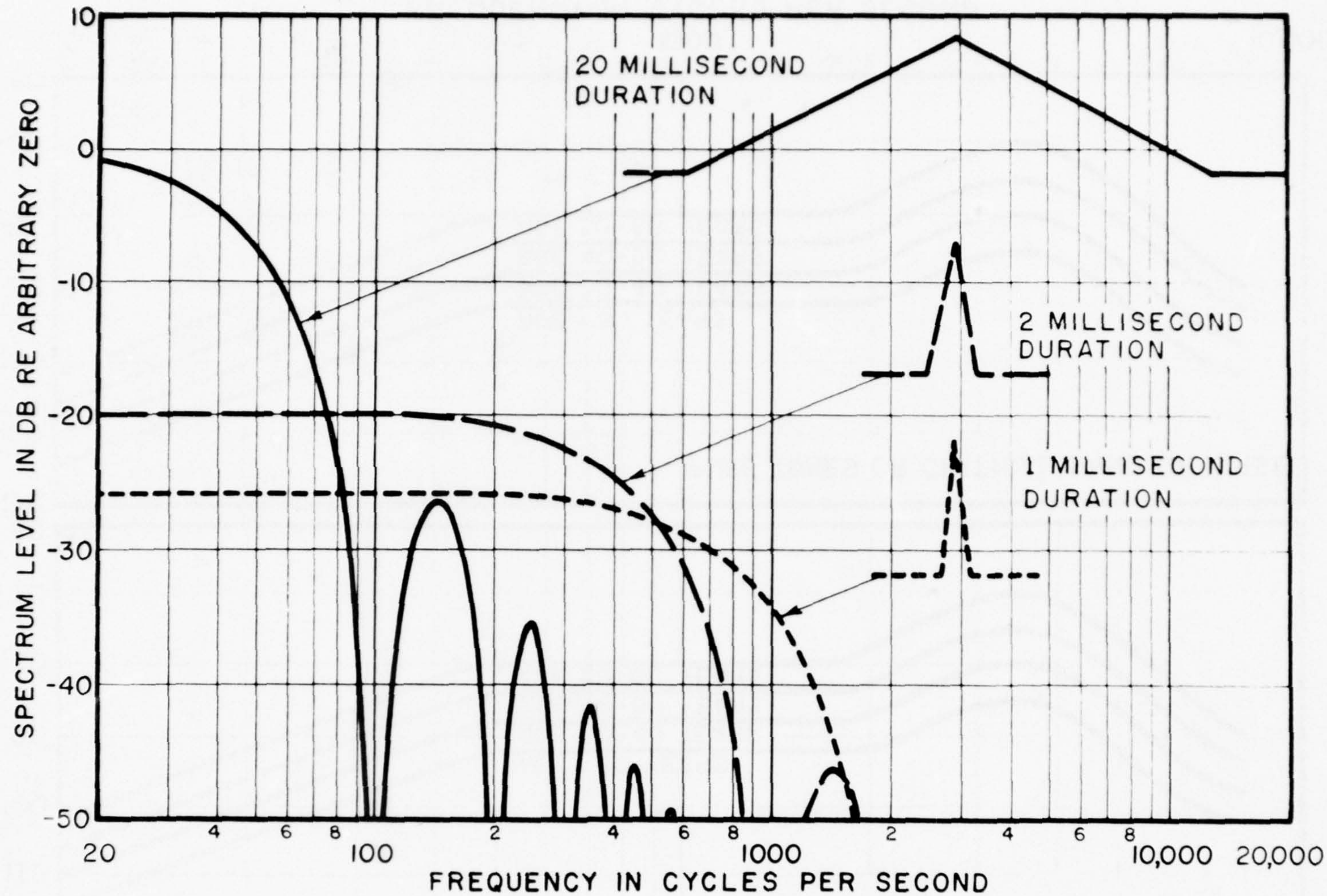

Figure 3. Frequency Spectra of Three Triangular Pulses of Equal Amplitude.

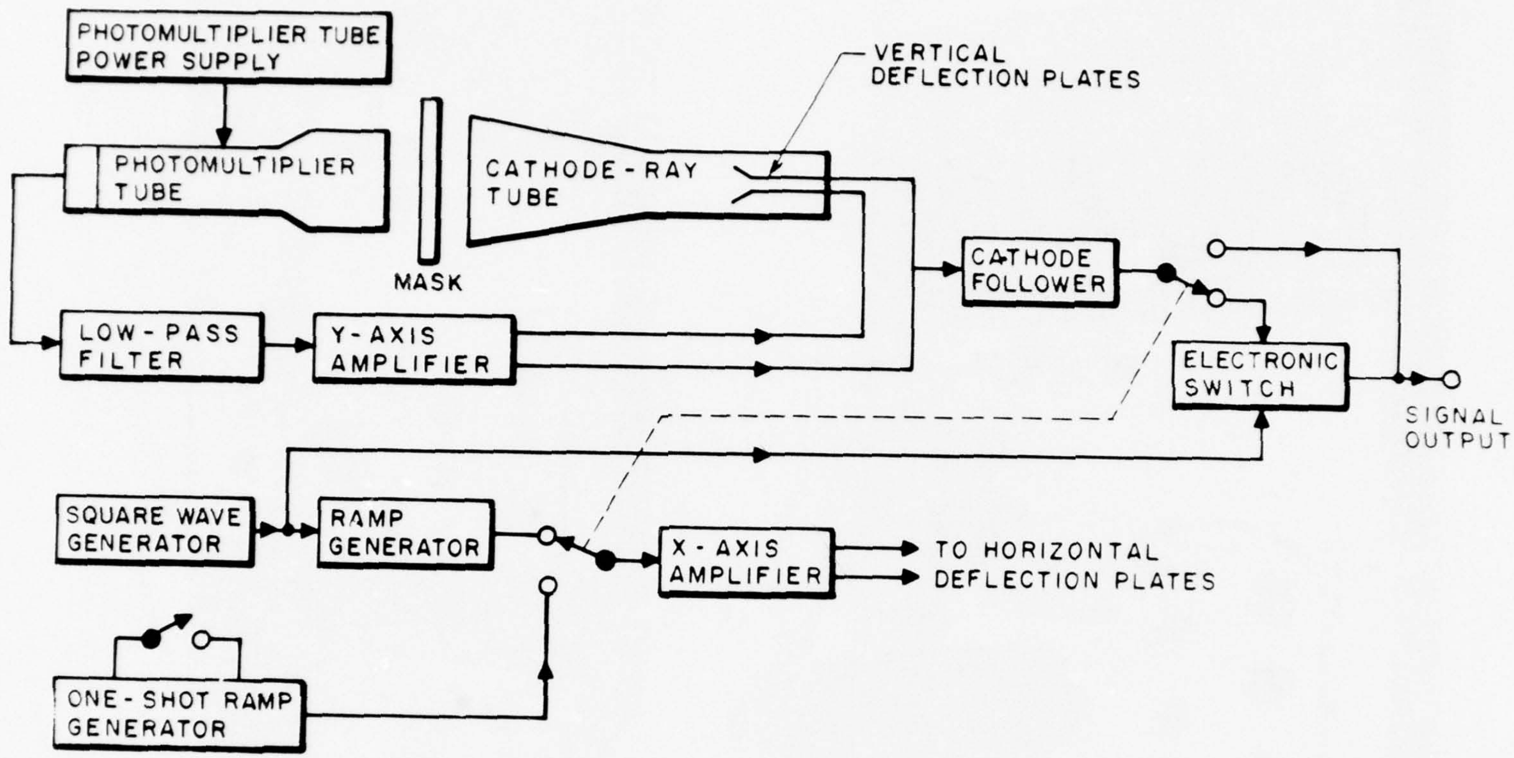

Figure 4. Block Diagram of Photoformer.

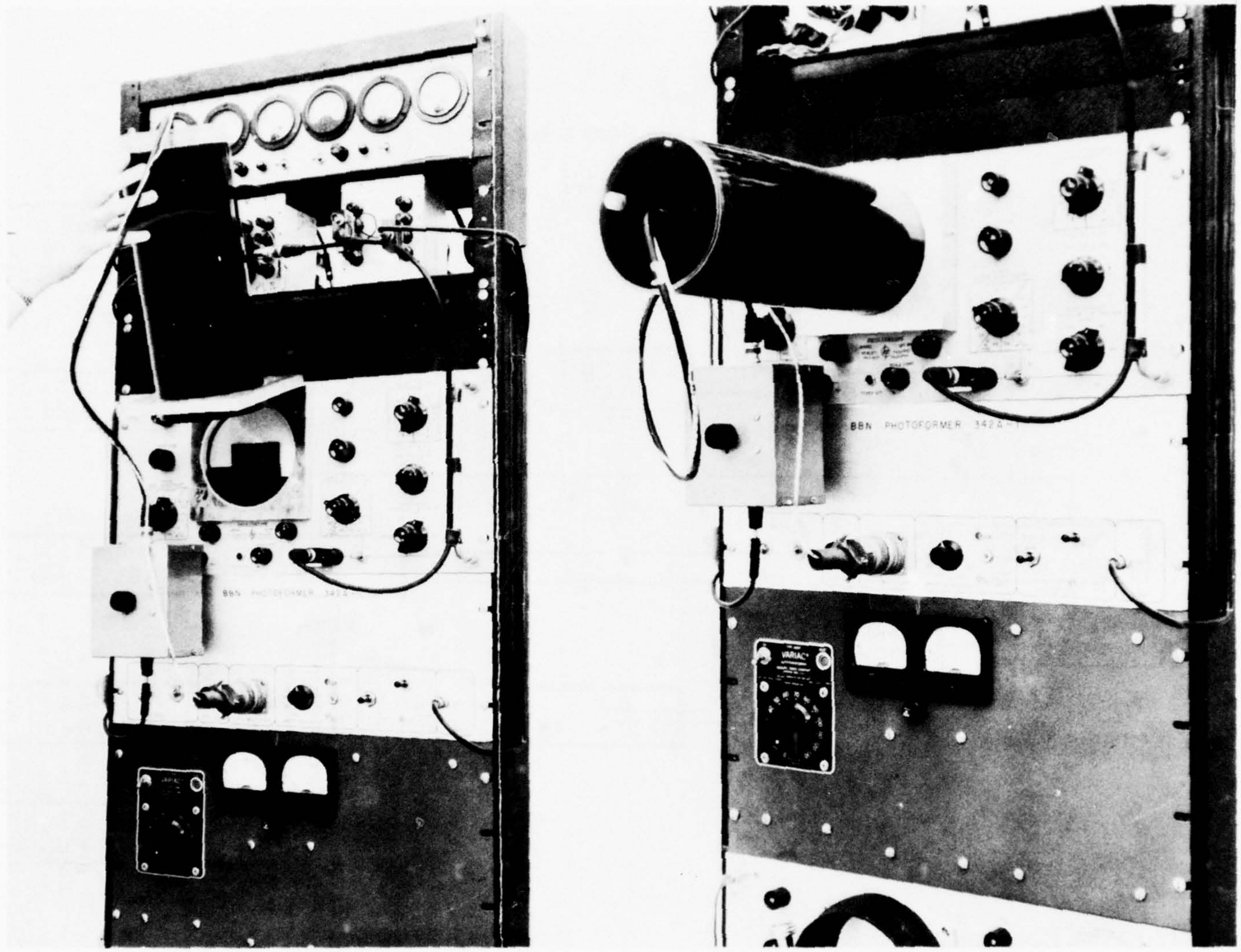

Figure 5. Photoformer and Associated Equipment.

Figure 6. The Diaphragm of the KLH Model 6.5 Loudspeaker Unit Can Be Seen Through the Opening in the Ear Cushion.

direct information is available, the formulae and procedures developed by Ward et al (2, 3, 4) from relatively steady state sounds probably represent the best way to predict the approximate effects on hearing of repetition rate and duration.

IMPULSE SOUND GENERATOR

In order to systematically explore the effects of impulse noise upon hearing, we have developed a system that has two special components:

1. a photoformer for the generation of an electrical impulse (see Figs. 4 and 5), and
2. a special loudspeaker-earphone that transduces this impulse into an acoustical signal (see Fig. 6).

Photoformer

The photoformer we use was developed by Jay Ball of the staff of Bolt Beranek and Newman and will be the subject of a technical report on this Contract DA-49-007 MD-985, to be forthcoming soon. Essentially, the beam of the oscilloscope will follow the shape of any mask placed over the face of the tube. Thus, by placing a properly shaped mask on the oscilloscope, we can obtain an electrical signal which varies in time in any way we wish.

We have prepared masks which will give us "spikes" or *impulses that vary in rise* time and decay time. We can change at will the rate at which the photoformer "fires" -- an important variable in causing deafness. The "spike" or "spikes" can be amplified to achieve different degrees of peak levels.

The photoformer has an additional feature which is important to this project. It can be used to correct, within certain limits, distortion caused by the loudspeaker-earphone transducer or by the acoustics of the earphone coupling. The signal produced by the loudspeaker-earphone -- determined by a microphone in a dummy-head (see Fig. 7) -- is compared to the original mask-waveform. If the measured pressure waveform differs from the one desired, the mask on the photoformer is changed to compensate for the error. This process is illustrated in Fig. 8.

Loudspeaker-Earphone

After considerable experimentation with a number of loudspeakers we selected for our investigations the Model 6.5, a dynamic unit built by KLH Research and Development Corporation, Cambridge, Massachusetts. By coupling this unit closely to the listener's ear we are able to generate a peak overall level of 170 db re 0.0002 microbar with an impulse having a 0.5 millisecond rise time. It will, of course, be appreciated that the high peak levels reached are permissible only for impulsive signals having durations of a few *milliseconds per* impulse. For steady-state signals with large peak amplitudes the unit would burn out.

Figure 7. High-Intensity Headphone on Dummy Head.

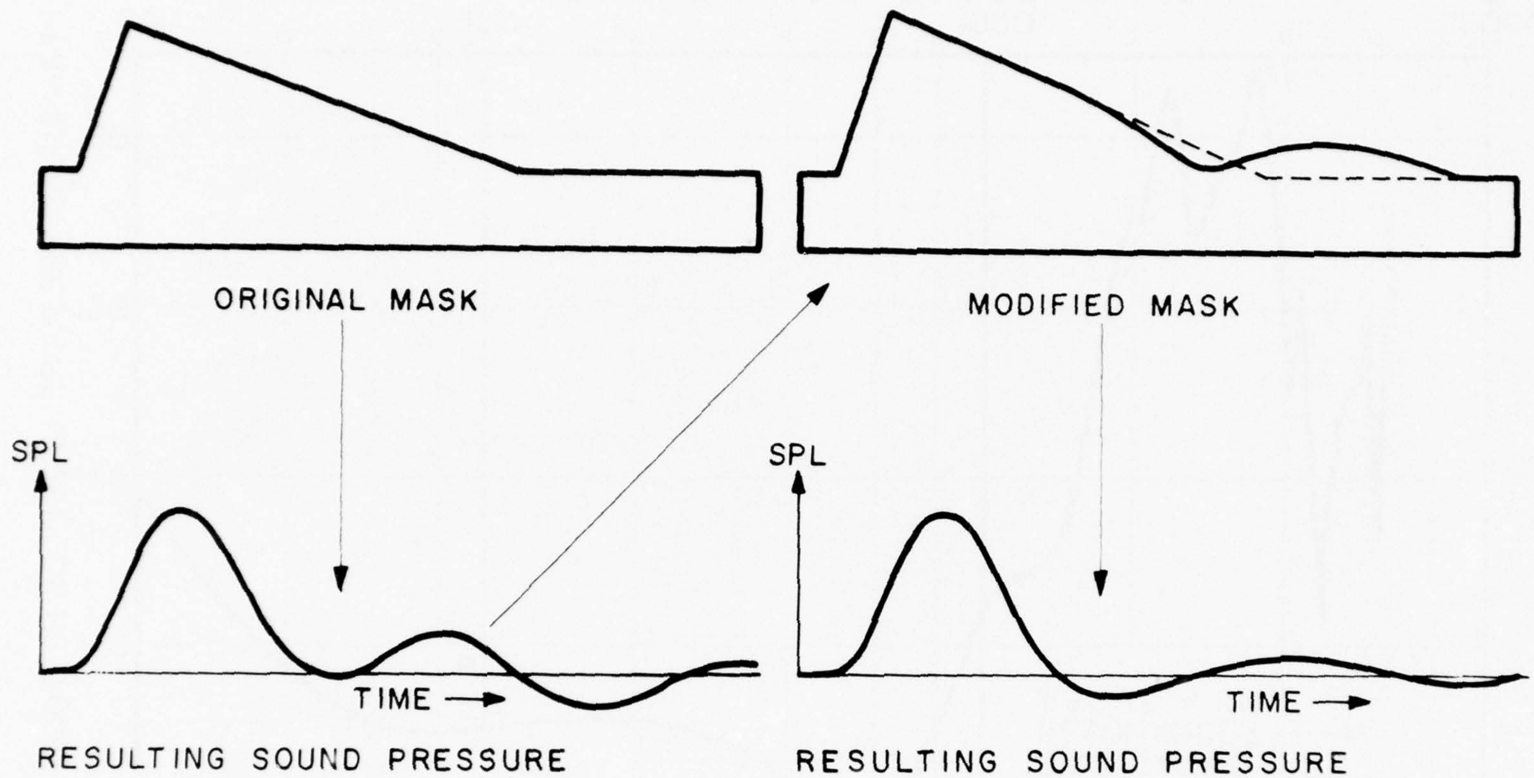

Figure 8. Compensating the Photoformer Mask for Loudspeaker Transient Response.

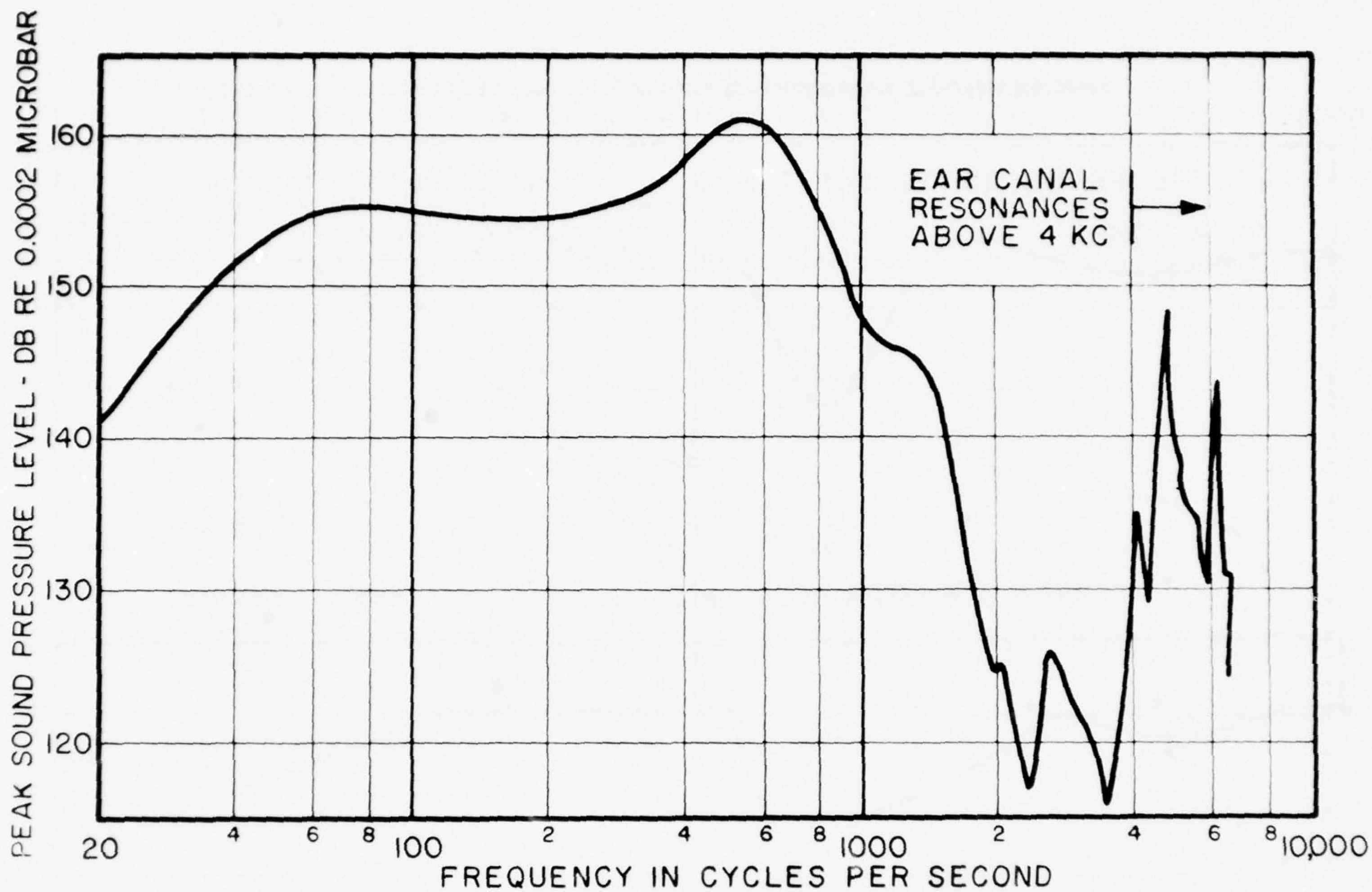

Figure 9. Pure-Tone Frequency Response of High-Intensity Headphone Measured on Dummy Head With Artificial Ear Canal.

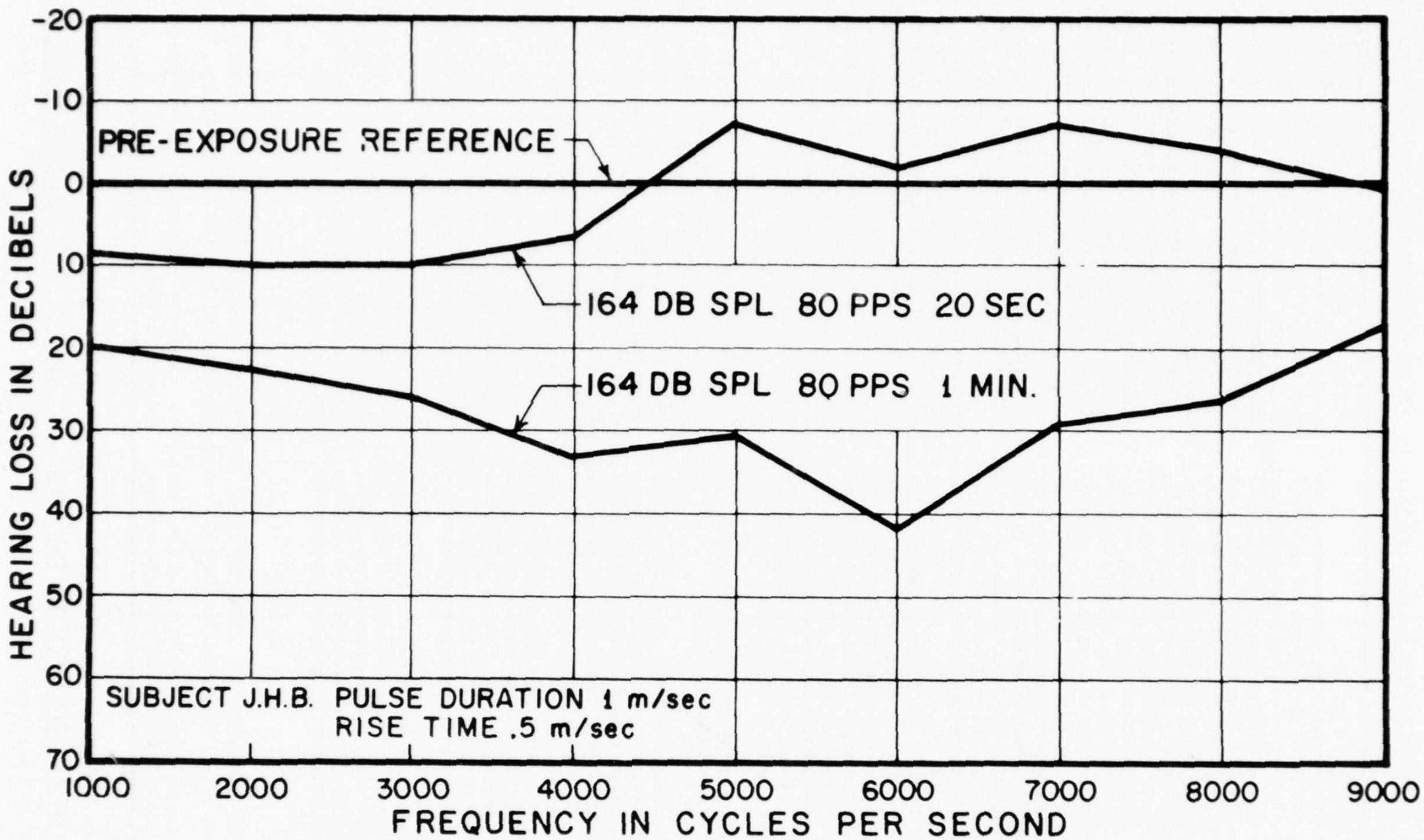

Figure 10. Temporary Threshold Shift Following Repetitive Impulse Stimuli

The pure tone frequency response of this unit is shown in Fig. 9. This characteristic was determined with the dummy-head microphone unit shown in Fig. 7.

We have investigated to some extent the characteristics of other types of acoustic impulse generators -- among these being exploding wires, an air pistol, a 10 gauge blank shotgun and a 22 gauge blank rifle with acoustic filters and attenuators on the muzzle. However, independent control of rise time, duration and peak level appears to be possible, without a costly development program, only with the photoformer and loudspeaker-earphone. Nevertheless, we want to emphasize that although we can vary the parameters listed above, we are limited with our present loudspeaker-earphone units to rise times no shorter than 0.5 millisecond. In view of the fact that rise times as short as .05 - .1 milliseconds are observed with Army weapons, it would be most desirable to obtain data on the deafening effect of impulses having those rise times. We believe that we can probably extrapolate to these very brief rise times from functional relations for somewhat longer rise times. Nonetheless, further development time and funds should be considered for the design and construction of a completely satisfactory electro-acoustical transducer for very brief acoustic impulses.

INVESTIGATIONS OF TEMPORARY THRESHOLD SHIFT

As aforementioned, to relate physical measures of weapon noise to damage to hearing we need hearing loss data as functions of sound pressure level, rise time, decay time, repetition rate, and number of repetitions of the impulse noise.

It is tantamountly impossible to investigate these relations in a way that causes permanent damage to hearing; it is nearly as difficult to determine from data on soldiers exposed to such noises the exact relations among these variables.

We can measure, however, the relative effects of these several characteristics of impulse noise upon hearing through measurements of auditory fatigue, or degree of temporary deafness resulting from exposure to these sounds.

Such a course of action is justified because of the close parallels that have been found between temporary deafness and permanent deafness; for example, for steady state sounds, the relations between spectrum content and permanent damage to hearing appear to be very similar to those found for temporary threshold shift. Also, one cannot distinguish by behavioral or auditory tests the difference between permanent and temporary hearing loss.

Our approach then is to attempt to sort out and find by laboratory experimentation with temporary auditory fatigue those physically measurable features of impulse noise that are the most reliable and valid ones to use in subsequent establishment of damage risk criteria for U.S. Army weapons.

At the time of writing this report we have just started to collect data on temporary hearing loss with the impulse sound generator. An example of the results on some of our initial tests are shown in Fig. 10. Systematic experimentation of the effects of peak level, rise time, repetition rate, and number of repetitions of sound impulses similar in their more important aspects to those possible from weapons will be conducted during the coming eight months under this contract to the U.S. Army Surgeon General.

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1. Doelling, N. and K. D. Kryter, "Characteristics of Noise Produced by Several Contemporary Army Weapons," Contract No. DA-49-007 MD-985, Research and Development Division Office of the Surgeon General, Department of the Army, Washington 25, D. C., March 1959.
2. Ward, W. D., A. Glorig, and D. L. Sklar, "Dependence of Temporary Threshold Shift at 4 KC on Intensity and Time," J. Acoust. Soc. Am., 30, 944-954, October 1958.
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B. COMMUNICATION BY ELECTRICAL STIMULATION OF THE SKIN by Capt Glenn R. Hawkes, MSC, US Army Medical Research Laboratory, Ft. Knox, Kentucky

Communication by stimulation of the skin has potential usefulness where the eye and ear are not available. This would be true for the blind or the blind-deaf. A similar situation arises when the receiver is in a high-noise environment, e.g. near jet aircraft. There are also certain specifically military uses of this type of communication, such as the need to preserve silence when on patrol near enemy positions.

The Braille system has been successful in making literature available to the blind. The complicated patterns of spatially arranged touch stimuli used in this system, however, require long training for response accuracy, and the delay involved in encoding material

into Braille severely restricts information transmission speed.

Many attempts have been made to train subjects to "hear" through the skin by applying to the fingers the vibrations produced by speech, but on the whole without much success. Gault (4) spent some 20 years of his life trying to accomplish this, and there have been more recent attempts. Such systems have proven useful in voice control training of the deaf, but identification of words requires considerable training and drops to the chance level when the speaker's voice is changed.

The basic difficulty with these studies has been the failure to appreciate the fact that the skin cannot make discriminations as fine as those made by the ears. What is needed is to assess cutaneous sensitivity to the types of signals likely to prove useful in communication. This has been done for mechanical vibration of the skin by Geldard's research group at the University of Virginia (5).

The three cues (intensity, duration and locus) used in the system depicted in Fig. 1, do not begin to exhaust the possibilities of sensory discriminations which could be used for signaling purposes. One immediately thinks of different frequencies of stimulation, since in audition stimulus frequency is the important determiner of pitch. Frequency discrimination, however, turns out to be rather poor. It takes from 20 to 33% increase in frequency from 25 cycles per second for a j n d, and about a 70% increase at 200 cycles per second. The poor frequency discrimination no doubt accounts for the failure of subjects to discriminate the differences among patterns of vibrations from a telephone loudspeaker cone carrying speech, as tried in Gault's early work.

Another possible cue that has been investigated is that of apparent tactual movement, analogous to visual "phi." This has been shown to be readily elicited under suitable conditions, and may well prove useful for a communication system designed to furnish directional information.

Rate of onset or offset of stimulation is still another possibility. Subjects can absolutely identify at least three rates of onset or offset of mechanical cutaneous vibration.

Another problem in the design of a cutaneous communication system is that of the meaning which shall be assigned to the signals used. Perhaps it is possible without too much training to have the various cue combinations stand for phonemes, and thereby greatly increase communication speed. Partial answers to some of these problems resulted from a symposium on this topic held at Fort Knox in February of this year. It was suggested that it may be possible to train subjects to use a system taught in Japan, where 10 consonant sounds and 5 vowel sounds, a total of 50 combinations, comprise the spoken language. Fifty written symbols represent these sounds, so that there is a direct correspondence between what is read and what is heard.

The discussion thus far has been concerned only with mechanical vibration of the skin. Vibratory sensations can easily be elicited by the application of the inadequate stimulus, electrical current. It should be possible to design an electrical cutaneous communication system analogous to that using mechanical vibration.

The use of electrical current for cutaneous signaling would permit easier stimulus control, and provide ease of design of the stimulator which rests on the skin. Electrodes are more easily mounted on the surface of the skin, are less bulky than vibrators, require only a tenth as much power, and can extend the usable frequency range at least tenfold. *These are* but a *few* of the advantages.

In designing an electrical cutaneous communication system, investigations may profitably be made of those cues already demonstrated to be useful in the mechanical vibration system, namely, intensity, duration, and locus of stimulation. An investigation of electrical cutaneous intensity discrimination could provide data necessary for the design of such a system.

Investigators of delta I for audition or mechanical cutaneous vibration have typically presented the stimuli to be judged by either the "beat" method, or the method of successive stimuli.

When using the "beat" method, the subject is required to detect variations in the stimulus intensity occurring at a rate of two or three per second. When using the method of successive stimuli, the subject is asked to compare the relative strength of two stimuli separated by a pause. With use of one or the other of these stimulus presentation methods, considerable differences in delta I values have been found both for audition and mechanical cutaneous vibration.

Care was taken in the present work to determine delta I values for only a single kind of sensation, vibration (cf. 2). Both the "beat" method and the method of successive stimuli were use in this experiment, since it would be desirable to know the differential sensitivity limits independent of the method of stimulus presentation. To facilitate comparison with delta I values when using the adequate stimulus, different intensity levels of the standard were used.

Three well-trained subjects participated in both parts of the experiment. The "beat" method used for the first part of the experiment involved variations of stimulus intensity at a rate of two per second. Current at frequencies of 100, 500, and 1500 cycles per second was applied to the finger tip. Due to large variations in absolute threshold values,

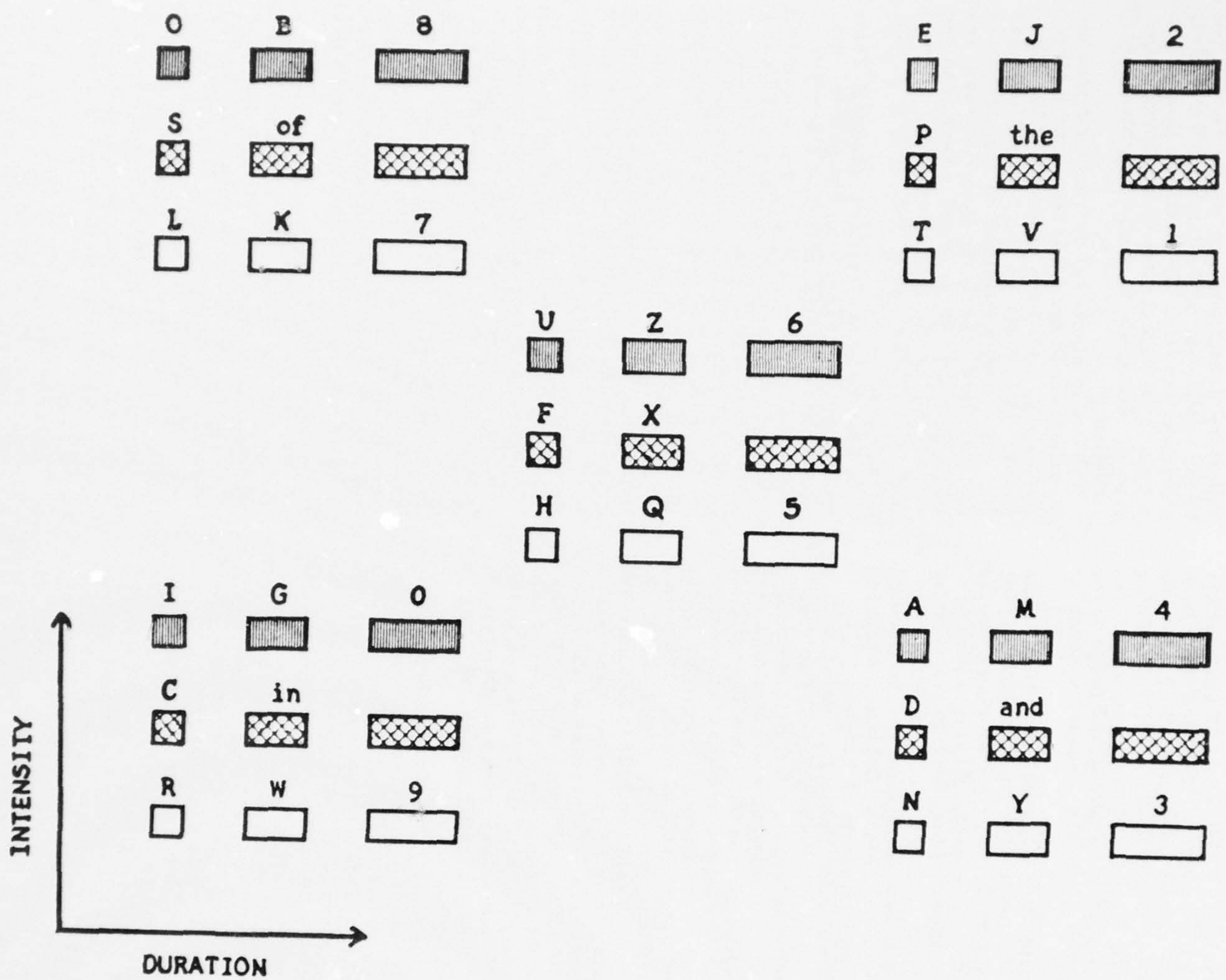

Figure 1. Mechanical Vibration Code Used by Geldard. The 5 groups represent signals applied to each of 5 vibrators positioned on the ventral thorax. Combinations of 3 intensity levels, 3 durations, and 5 loci yield 45 combinations to which were assigned the code meanings shown.

the absolute threshold (RL) was measured daily for each subject, and standard intensity levels were used which had a constant ratio to the absolute threshold. Values selected for use were 120% and 200% of the current necessary to reach the RL, this range avoiding pain. The Method of Limits was used with a stimulus of four seconds duration. A block diagram of the apparatus used in most of the experiments described in this paper is shown in Fig. 2.

The method of successive stimuli was used in the second part of the experiment. Two 2.0-second stimuli, separated by a 2.0-second pause, were presented at either 100 or 1500 cycles per second. The Method of Limits was used with a counterbalanced order of presentation. Fig. 3 shows the results when using the "beat" method; nearly identical results were obtained for the method of successive stimuli.

The most noticeable difference between the results of the present study and the results of other investigators was the failure to find a difference in the size of delta I with different methods of stimulus presentation in the present instance.

A possible explanation of the lack of difference for the two methods in the present data may be that the disparity in delta I values reported in mechanical vibration, or in audition, by different investigators, is more apparent than real. These investigators used only a single stimulation method in a given study, and, therefore, data are not available using more than one stimulation method on the same subjects. In the present study, the comparison of the two methods involved the same subjects, equipment, and calibrations.

The present results are in agreement with studies of delta I in other modalities in that the size of delta I was larger at weak standard intensity levels than at higher intensities of the standard stimulus. Weber fraction values are smaller, however, for electrical stimulation of the skin than for audition or mechanical cutaneous vibration.

This information on the size of delta I indicates discrimination limits under laboratory conditions. Communication systems, however, require the subject to identify a number of signals transmitted to him at relatively rapid rates. The ability of a subject to make absolute identifications of intensity levels must therefore be investigated in order to select signals which will minimize confusion and errors.

In a recent review article on information theory, Alluisi (1) listed four factors which determine efficiency of absolute identifications: the number of response categories in relation to the number of stimulus categories; the spacing along the dimension in question of the stimuli to be identified; knowledge of results; and the extent of the physical range of stimulation used.

In the study of absolute identification of vibratory intensity on which Geldard's system was based, the stimuli were an equal number of j n d's apart along the intensity dimension. This spacing procedure assumes equality in size of the j n d's. Investigations of a number of sensory continua by Stevens have demonstrated that j n d's are not necessarily subjectively equal (14).

The method of "magnitude estimation" used by Stevens has usually involved the judgments of a number of observers whose task was to assign numerical values to stimuli along a given dimension in such a way as to express their subjective relationship to a standard stimulus. Data on most of these continua have yielded functions which, plotted in log-log coordinates, may be fitted by a straight line whose slope is the exponent of a power function, relating the physical dimension to apparent magnitude of the sensation. The slope of the line which best fitted such data for intensity of electrical stimulation of the skin was reported by Stevens to be 3.5, the largest slope of any of the continua tested (15).

Fifteen subjects were asked to report the apparent magnitude of sensation. Eight received stimulation at 100 cycles per second in the first session, and 1500 cycles in the second session; the remaining subjects received 1500 cycles per second in the first session. The results, plotted in Fig. 4, indicate no difference due to frequency. The slope was 3.5.

I was interested in discrimination of electrical intensity levels for the possible use of intensity as a cue for signaling purposes. It was necessary, therefore, to determine the number of intensity levels which could be absolutely identified. The intensity levels used in this study were equally spaced in terms of apparent subjective magnitude of sensation. Twenty-four subjects participated in this experiment. Eighteen were enlisted men stationed at Fort Knox, and the remaining six were experimental psychologists from our ARML staff. The latter six were designated as the "sophisticated" group, and the remaining as "naive."

Twelve "naive" subjects were stimulated with alternating current at a frequency of 100 cycles per second; the remaining subjects received stimulation at 1500 cycles per second. Half of the 1500 cycles per second group were "naive" subjects, half were "sophisticated." Each subject participated in four sessions, with each session being devoted to identification of a different number of intensity levels. Half of the subjects received five intensity levels during the first session, four levels during the second session, etc.; the other subjects received two intensity levels during the first session, three levels during the second session, etc. The subject was presented 100 stimuli for identification in

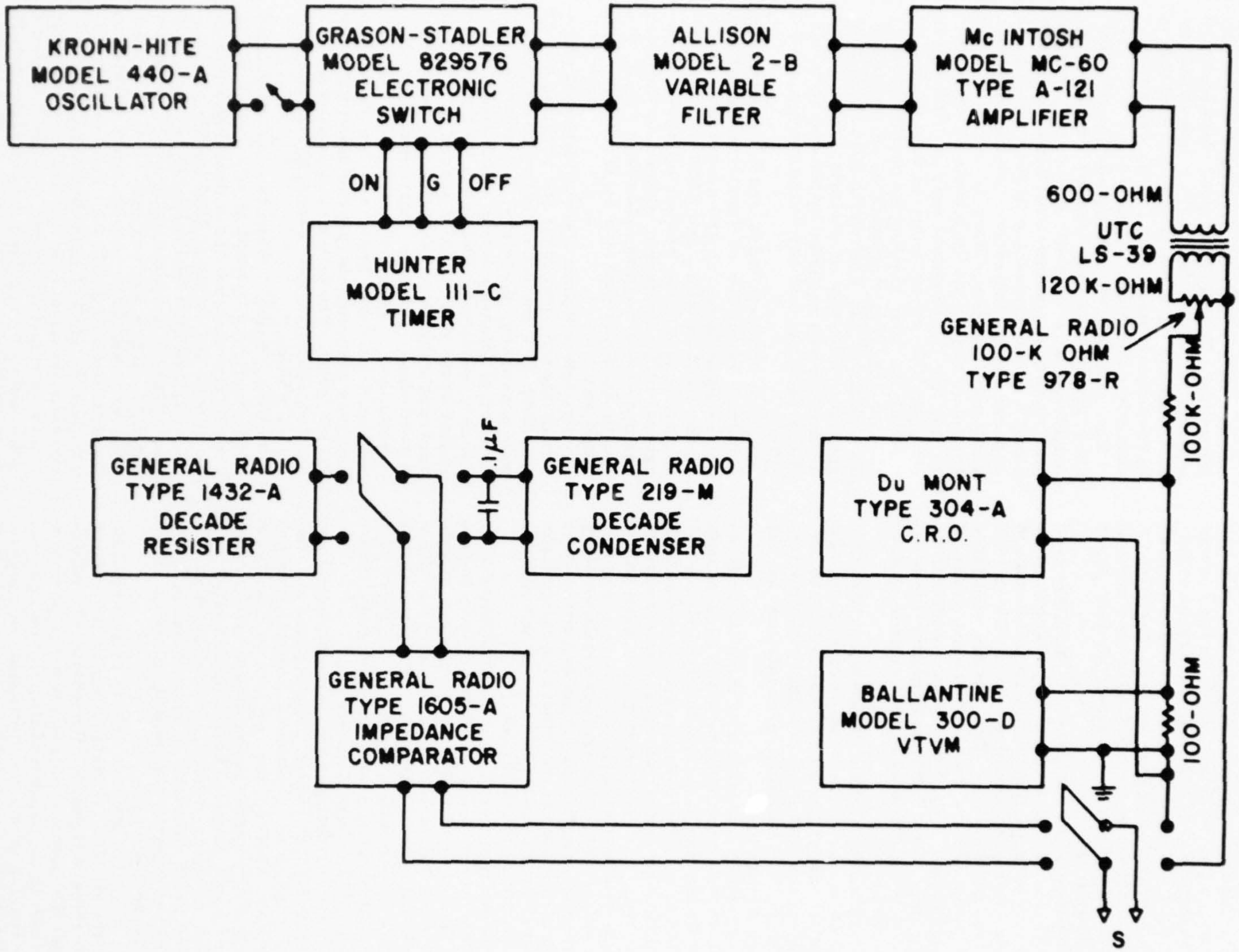

Figure 2. Block Diagram of the Apparatus Used in These Studies.

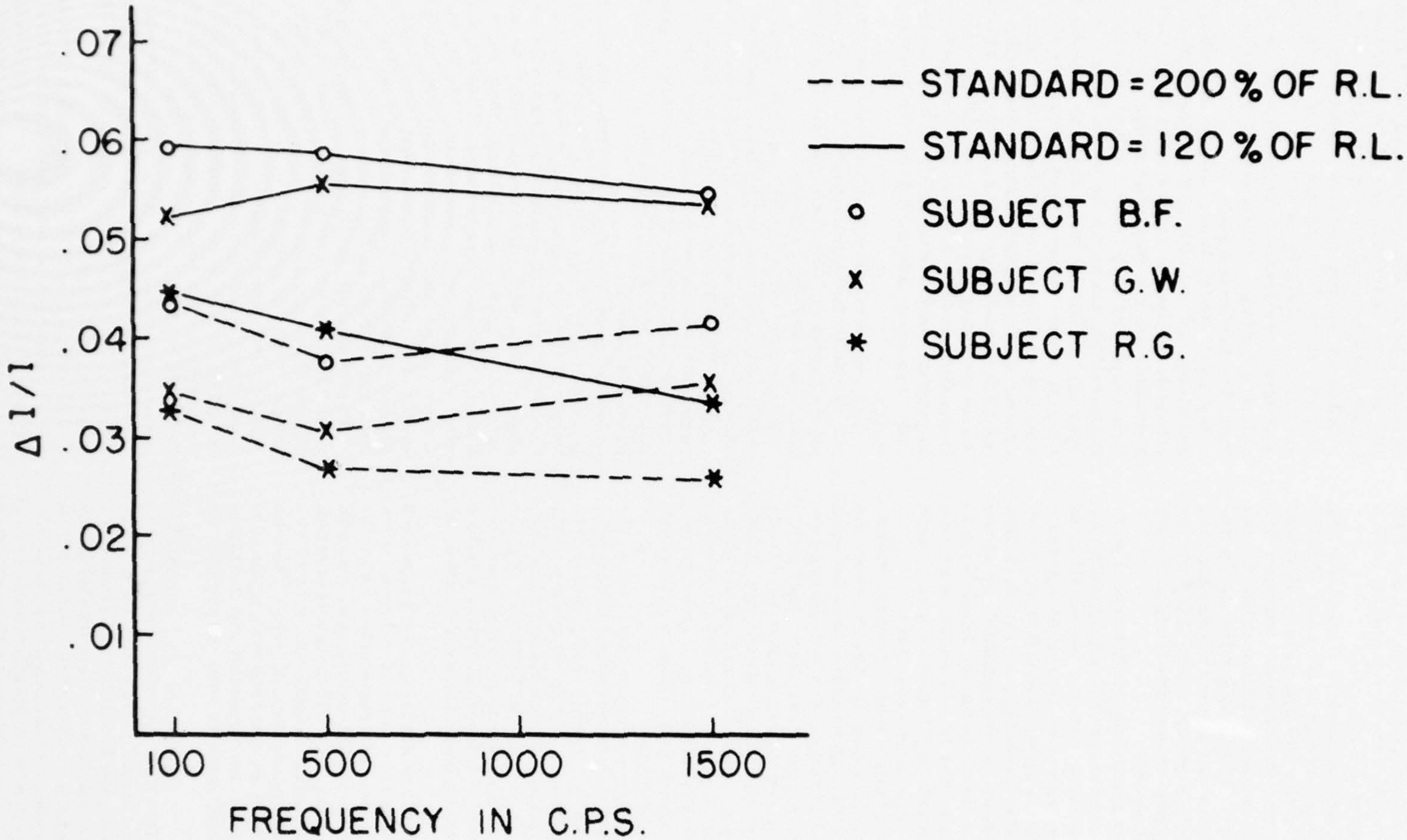

Figure 3. △ I/I As A Function of Standard Intensity Level and Frequency for 3 Subjects. The Signal Fluctuated in Intensity At A Rate of 2 Per Sec.

each session. Stimulus duration was one-half second, and stimuli were presented at a rate of about one every 2.5 seconds.

The results are plotted in Fig. 5 for the 1500 cps group. Function forms are similar to the results of the 100 cps group. A t-test was made of the differences between the "amount of information transmitted by the average subject" (1 p. 98) for the group receiving 100 cycles per second versus the 1500 cycles per second group. The 1500 cycles per second group transmitted significantly more information (8).

If, in a given situation, 100% correct performance is necessary for communication involving alternating current stimulation of the skin, then only two levels of intensity should be used. It appears that it is possible, however, to take advantage of the fact that more information is transmitted by three categories than two if intensity level is combined with other cues to add redundancy to a message. Contect might also help to reduce the number of incorrect responses.

I mentioned earlier that increased transmission of information is found when the subject is afforded immediate knowledge of results. Such knowledge was not afforded the present subjects, however, for most communication systems do not permit such feedback. Also reported was a gain in information transmitted as a result of extending the physical range of stimulation. The physical range of the present investigation, however, was restricted in order to avoid pain sensations for most of the subjects.

It would be interesting to determine the effect on information transmitted of extended physical intensity range and immediate knowledge of results. Prior to such a study it became necessary to determine what current intensities could be tolerated by the subjects without emotional reactions, and the reliability of such tolerance limits relative to the absolute thresholds for vibration or pain.

After preliminary training, the responses of each of two highly trained subjects were recorded with use of frequencies over the range of 100 to 10,000 cycles per second. After determining the vibration threshold, current was increased until the subject reported the first appearance of pain. Then an additional amount of current was applied to the subject until he reported the terminal limen. Typical results are presented in Fig. 6.

Qualitative reports of the sensations elicited by electrical stimulation indicated that vibration typically was felt as a weak "tingling" sensation localized in a small area under the active electrode. Pain was typically a localized sensation superposed on the vibration, and described as similar to the sensation elicited when a needle point is just penetrating the skin. The terminal limen typically was reported to be like sensations of "burning" and muscle contractions, of an apparent intensity which could not long be endured.

Subjects in the present experiment were able to report the terminal limen as reliably as the pain Reizlimen or the vibration RL, and after preliminary training evidenced no undue emotional reactions to stimulus intensities producing pain.

My next study, then, was of the effect of knowledge of results and extended physical intensity range on information transmitted. Extension of the physical range of stimulation employed may indeed affect information transmitted, probably by permitting a wider spacing of the stimuli, thereby making the stimuli more closely approximate 100% jnd spacing on the intensity dimension. Any increase in information transmitted when immediate knowledge of results is afforded would probably be due to "anchoring" effects. Immediate feedback to the subject could tend to prevent shifts in adaptation-level and provide repeated anchoring of the subjective scale.

Ten subjects were used in this experiment, all of whom had participated in the previous study involving the absolute identification of levels of current intensity.

Four sets of stimuli, equally spaced in terms of apparent subjective magnitude of sensation, were selected for absolute identification. The stimulus intensity range was between the vibration RL and three times the current value at the RL, as compared to only two times the RL current value used in the previous study.

The subjects were divided into two matched groups on the basis of previous performance. Subjects in Group 1 made absolute identifications of current intensity levels as in the prior experiment, but with the extended physical intensity range. In addition, they were informed of the correct value of the stimulus after making each judgment. Subjects of Group 2 received identical current intensity levels for identification, but were not afforded immediate knowledge of results. The data are plotted in Fig. 7.

The relatively small span of absolute judgment for current intensity levels, and the relatively rapid rate of increase in perceptual error with additional uncertainty of the subject, indicates that the use of intensity as a cue for signaling purposes would be limited to three levels in a communication system requiring a high level of accuracy, and to four levels in a system capable of tolerating some error in order to maximize information transmitted. This is true even with extended physical intensity range and immediate knowledge of results.

The next aspect of discriminability of electrical cutaneous stimuli investigated was the ability of subjects to distinguish differences in stimulus duration. In order to assess the

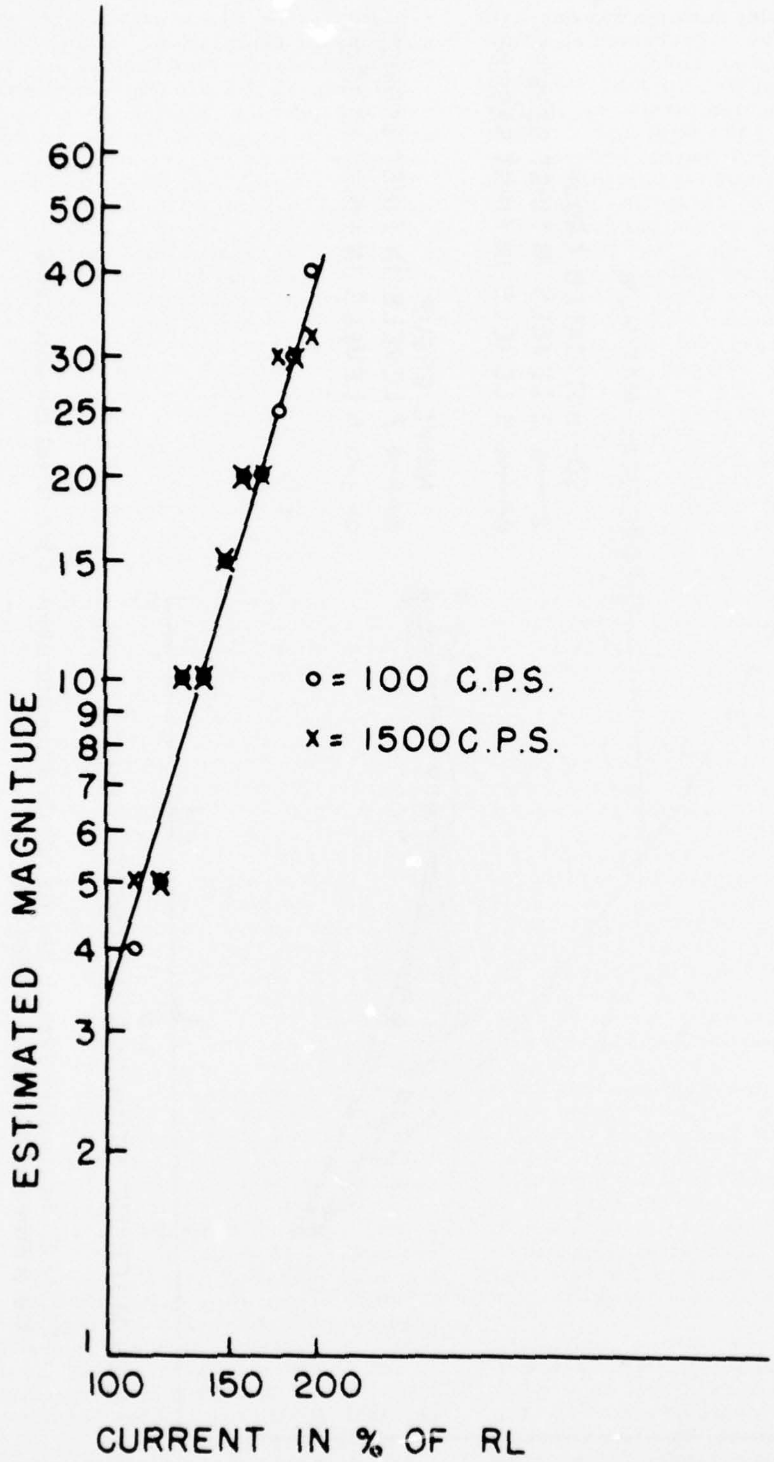

Figure 4. Direct Estimates of Apparent Electrical Intensity for 2 Stimulus Frequencies. 15 Subjects.

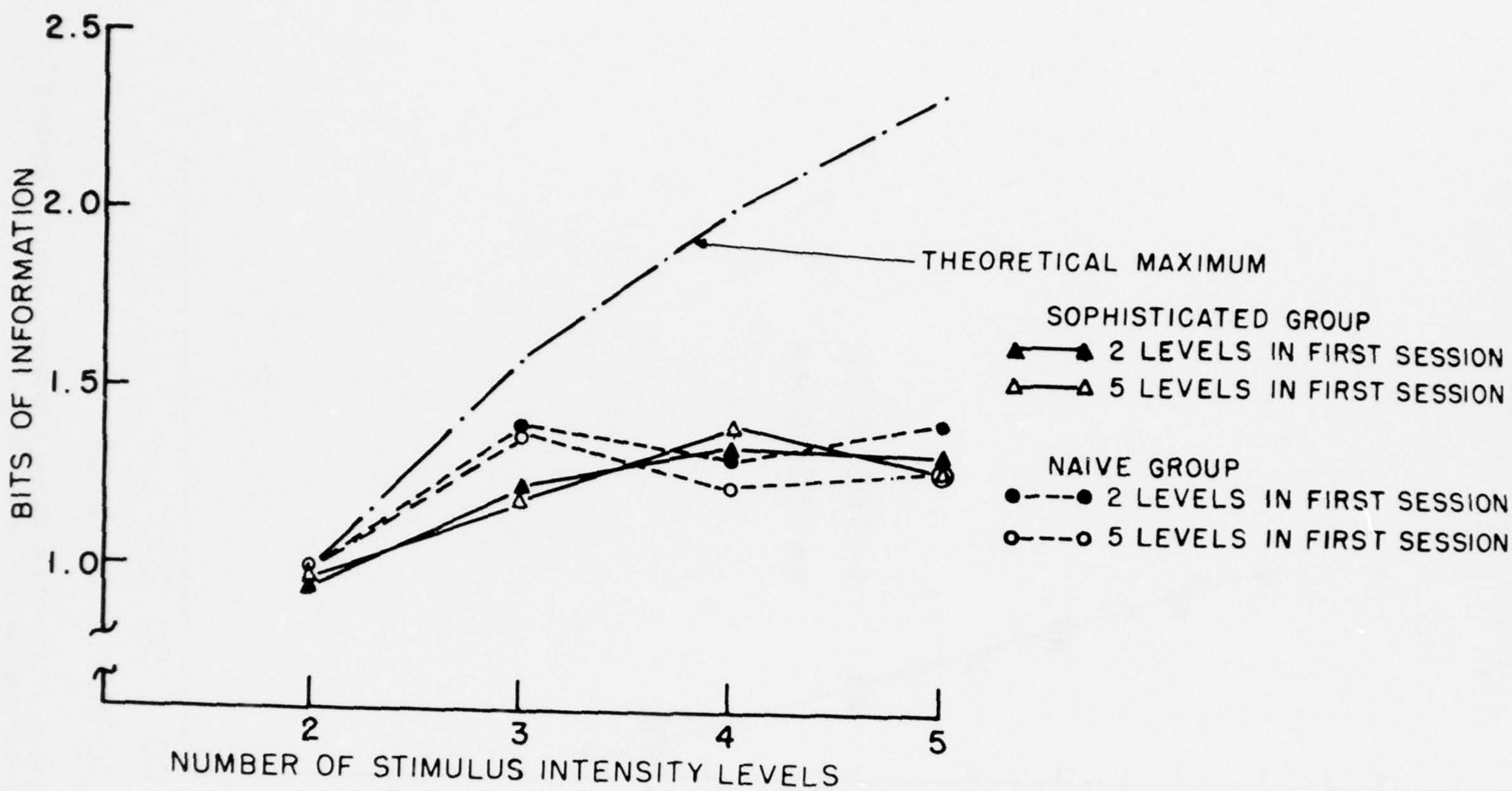

Figure 5. Information Transmitted via Absolute Identifications of Electrical Intensity Level With A Stimulus Frequency of 1500 CPS.

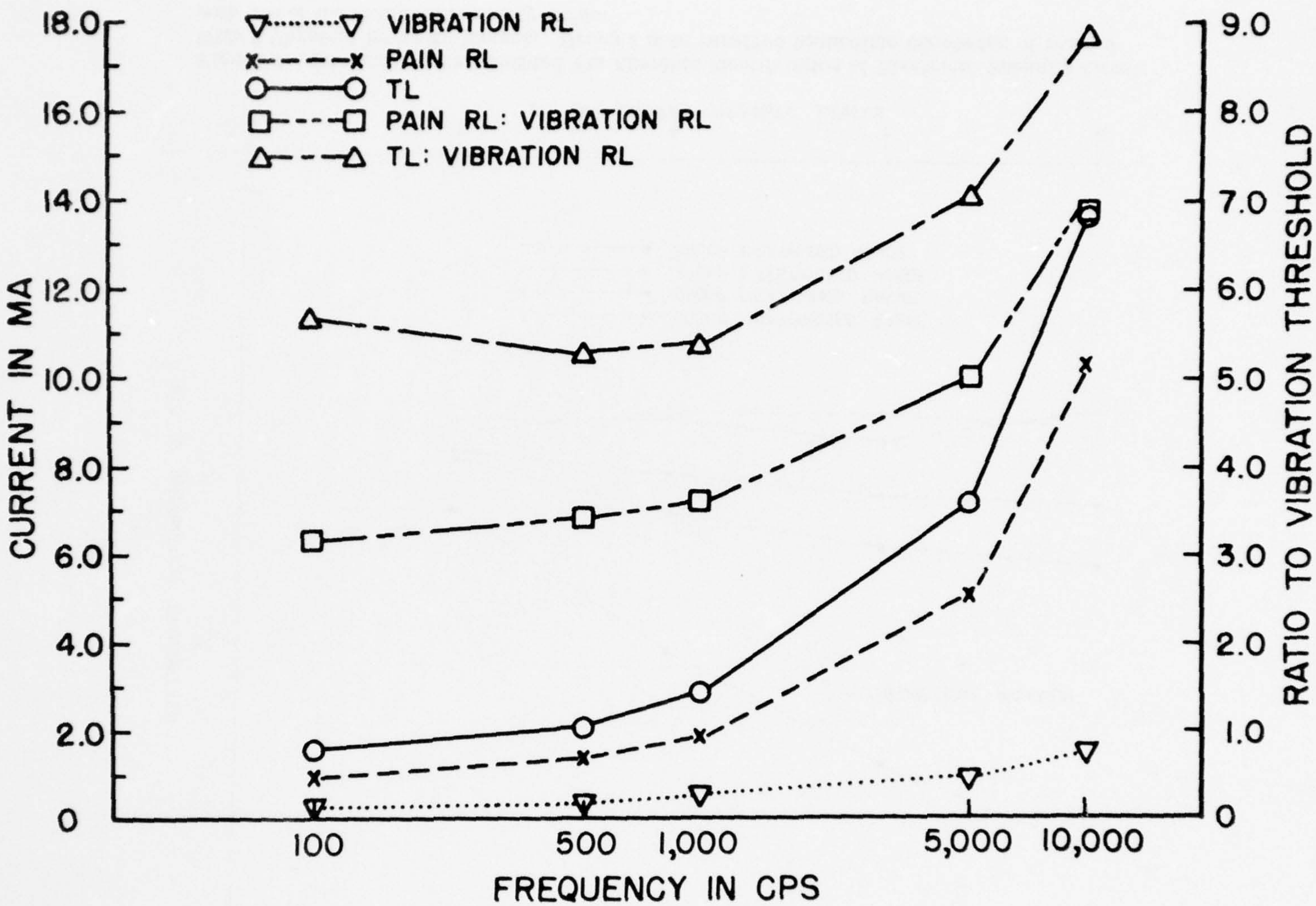

Figure 6. Electrical Vibratory and Pain Absolute Thresholds and the Tolerance Limit, for Electrical Current Applied to the Finger, As A Function of Stimulus Frequency. Usable range of current is shown (right scale) as the ratio to vibratory RL (absolute threshold).

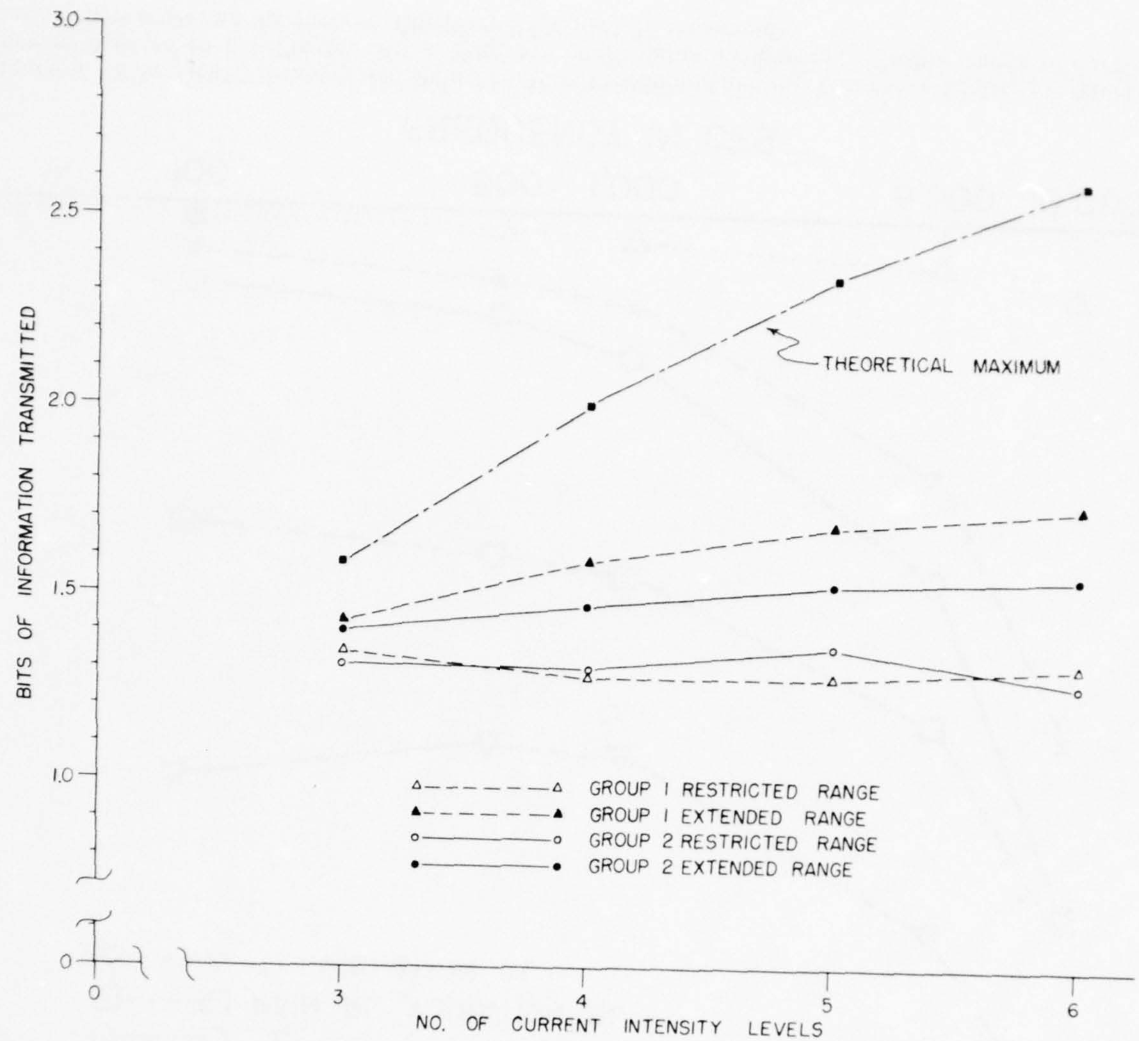

Figure 7. Information Transmitted Via Absolute Identification of Electrical Intensity Level With 2 Physical Intensity Ranges. Group 1 also received immediate knowledge of results with use of the extended intensity range.

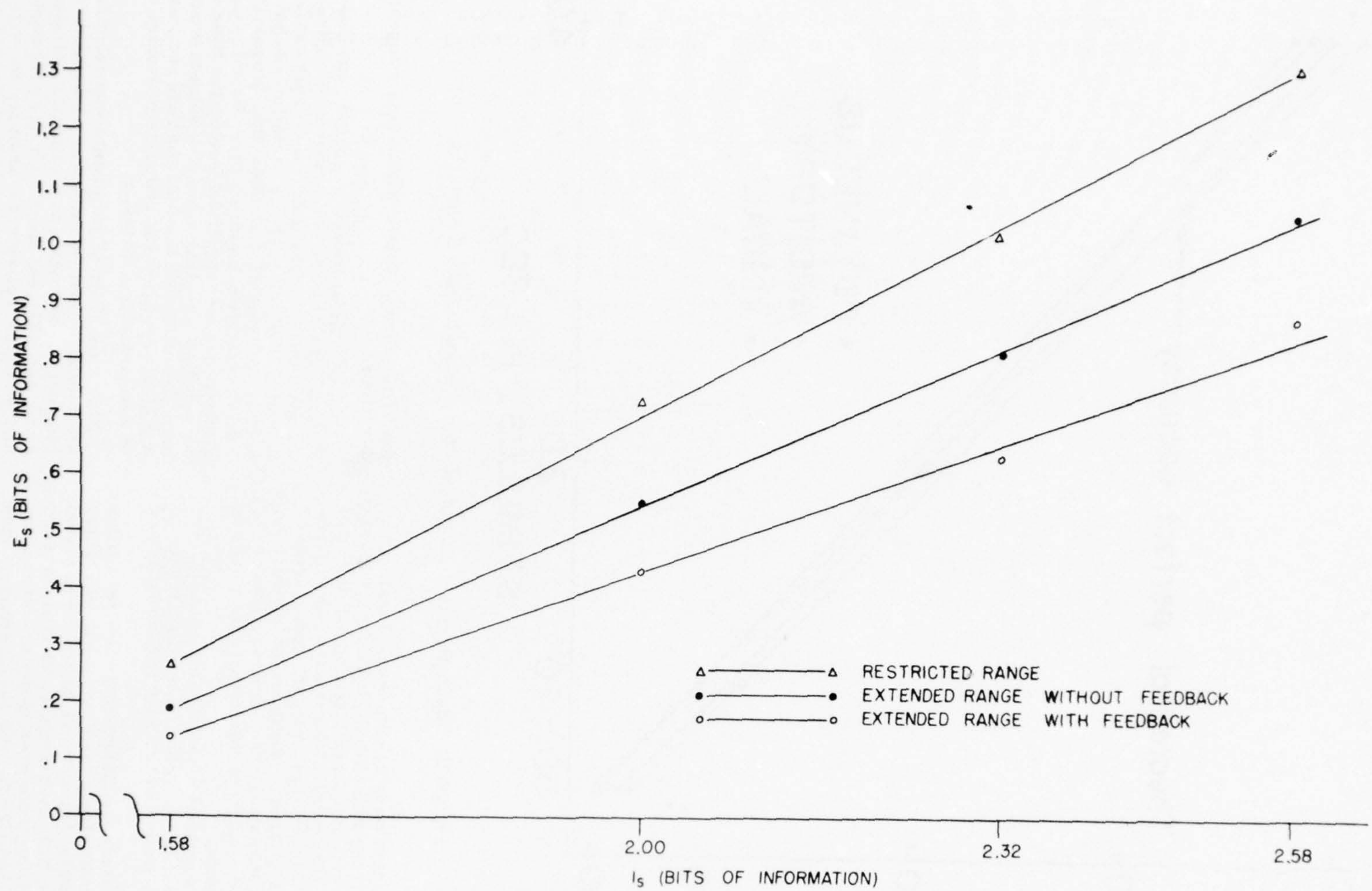

Figure 8. Equivocation of the Subjects As A Function of the Amount of Information in the Stimulus Display. Lines fitted to these data had slopes of 1.03 (restricted range), 0.94 (extended range without feedback), and 0.72 (extended range with feedback).

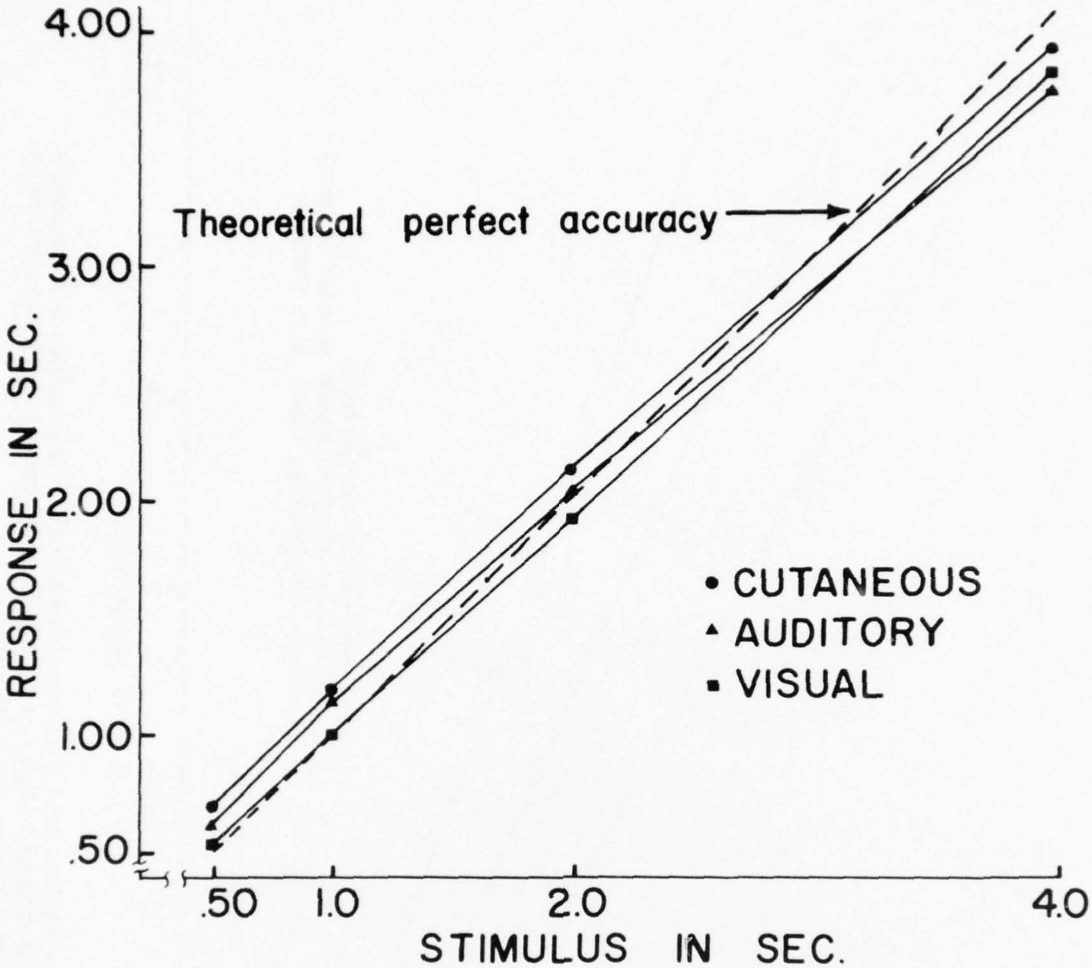

Figure 9. Mean Duration Judgments for 3 Modalities. 9 Subjects.

relative usefulness of cutaneous duration vs. more conventional stimuli, in the first experiment the relative magnitude and reliability of duration judgments of 9 subjects were investigated for auditory, visual, and electrical cutaneous stimuli. Methods of production, verbal estimation and reproduction were used, with stimulus durations of one-half to four seconds.

Mean results for the three modalities are shown in Fig. 9. Significant differences in response times were found for modality and interval.

The cutaneous judgments did not differ significantly from auditory, but did differ significantly from those based upon visual stimuli. The indifference interval, or point of transition from over to under-estimation, varied from 1.26 to 3.60 sec., dependent upon modality, indicating that maximum discriminability should occur within this range of durations.

Method differences reported in other studies (see 3) were not apparent upon direct comparison. A significant rank-order correlation of -.78 for verbal estimation and production judgments indicates that judgments with these two-methods are based upon similar processes. If the subjective time is faster than physical time, the subject would turn on a stimulus for less than one sec., and would overestimate a stimulus presentation of 1 sec. physical duration.

High reliability of judgments was found for all methods and modalities. Inasmuch as judgments of cutaneous stimulus duration were not different from auditory judgments, and were as reliable as auditory or visual judgments, it may be concluded that the use

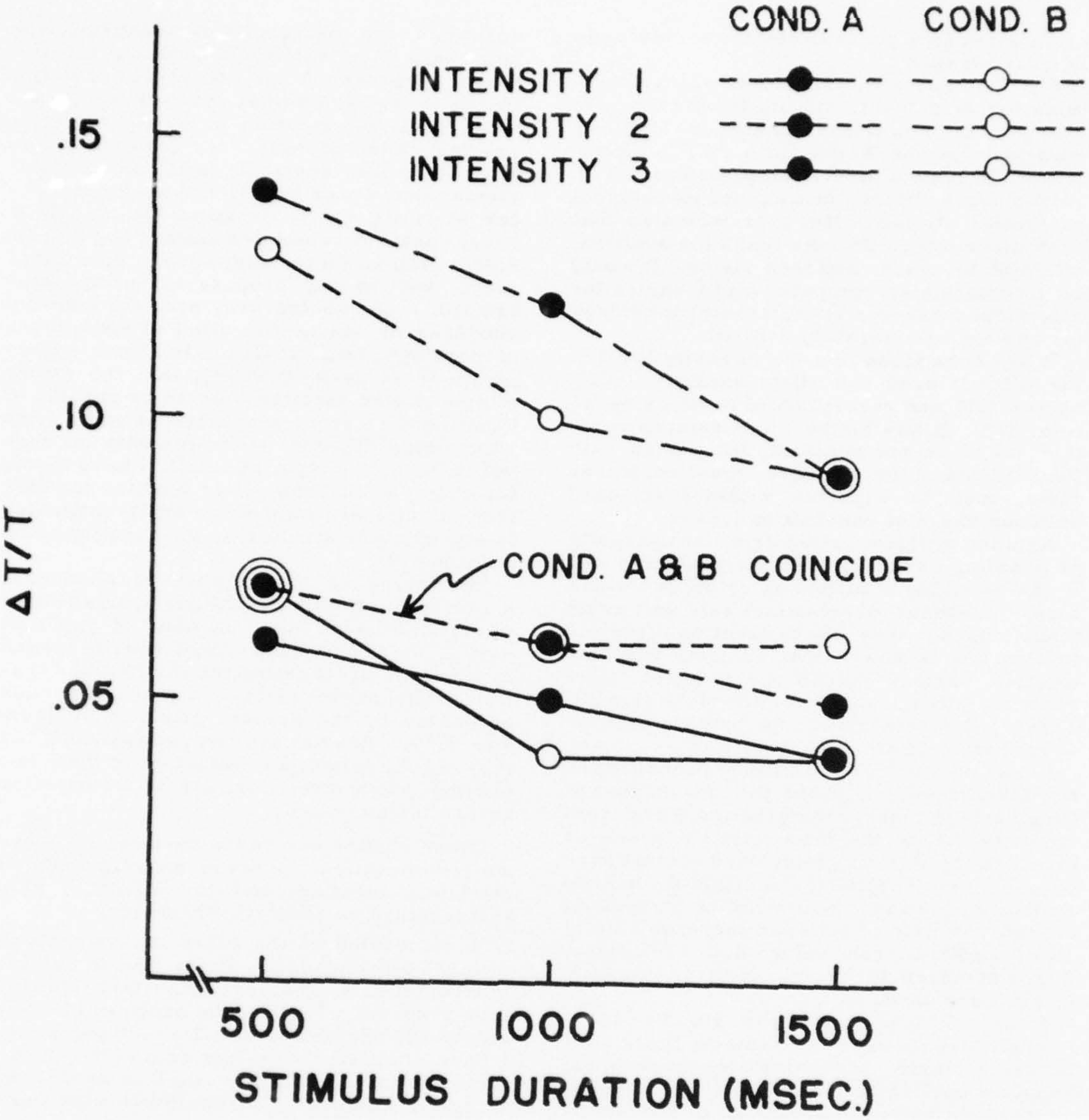

Figure 10. The Weber Ratio for Stimulus Duration Using 3 Intensity Levels and 2 Onset-Offset Conditions.

of duration as a cue in an electrical cutaneous is quite feasible.

My next concern, therefore, was a determination of subjects' ability to discriminate changes in electrical cutaneous stimulus duration, i.e. the Weber ratio $\Delta T/T$. Goodfellow (7) made a direct comparison of $\Delta T/T$ valves for auditory, visual, and mechanical cutaneous stimuli. His data indicated that best discriminability was found for audition, followed by touch, and then vision. It would be interesting to compare $\Delta T/T$ values for electrical cutaneous stimuli to similar values for auditory or vibratory stimuli.

It has been found that the intensity level of the stimuli used can affect auditory $\Delta T/T$ values (10) and perception of auditory duration (12). It has further been demonstrated that $\Delta T/T$ is not constant, but varies with the duration of the standard. Smallest Weber ratios may be expected within a standard duration range of one-half to 1.5 sec.

Another problem arises from the necessity of avoiding switching transients which occur if the stimulus is turned on or off at a rapid rate. A slower onset-offset rate will avoid transients but may affect duration discrimination. It is known that subjects can distinguish various transientless onset-offset rates for electrical stimulation of the skin (6). These judgments appear to be very similar to estimates of stimulus duration.

In one part of this experiment (Condition A) the stimuli were equated for the amount of time devoted to increasing the applied current from the RL to the peak intensity level, 25 msec. of the interval being used for this purpose. The other part, Condition B, utilized stimuli equated for the amount of current increase per unit of time, an increase rate of 1% of the RL current value each .4165 msec. Three standard durations and three intensity levels were used.

Mean $\Delta T/T$ plotted in Fig. 10. The three intensity levels were the same as those used in the intensity discrimination experiment reported earlier. Standard durations covered a range of 0.5 to 1.5 sec. Use of a weak intensity level (I_1) yielded significantly larger $\Delta T/T$ values, but there was no difference between the use of the middle and high intensity levels (I_2 and I_3). Further, the 0.5 sec. standard duration resulted in significantly larger $\Delta T/T$ ratios, but the 1.0 and 1.5 sec. standard durations did not produce significantly different results. In addition, no difference in $\Delta T/T$ resulted from differences in rate or time of stimulus onset or offset. Both intensity level and standard duration being significant effects, these data support a hypothesis of Holway and Hurvich (11) that discrimination is changed with either an intensity or duration change of the standard stimulus.

The next logical experiment is to determine how many electrical cutaneous stimulus durations can be absolutely identified, i.e. how many durations would be useful for signaling purposes. A basic tenet of information theory is that an optimal condition for transmission of information is equal subjective spacing of the stimuli. The question is how to achieve this desirable goal. The experimenter may space the stimuli an equal number of jnd's apart, or space the stimuli an equal apparent subjective amount by Stevens' direct estimation technique (13). I am interested, but do not propose to become embroiled, in the controversy over the inherent goodness of one or the other of these types of psychophysical scales. It seems appropriate to remark, however, that the rather simple power function said to be capable of handling data from a number of modalities when using Stevens' technique may not turn out to be very simple after all. I have found, for example, that the power function for data from electrical cutaneous intensity estimates is significantly affected by the duration of the stimulus (9).

The study of the number of absolutely identifiable stimulus durations utilized stimuli spaced by an equal number of jnd's in part 1. Part 2 utilized stimuli equally spaced in terms of direct estimates of stimulus duration. The power function exponent for such estimates by the present group of subjects was 1.19. Results are not yet analyzed, but they should permit an evaluation of these two scaling procedures for use in information transmission studies.

Other studies now in the data-taking phase are on the effect of drugs on judgments of stimulus duration, and the effect of skin temperature on absolute thresholds.

A discussion of the other experiments in which I am engaged I would like to delay a moment to take up a very important topic for this program. That is, the problem of evaluating the usefulness of cutaneous signaling. I have suggested uses for skin communication in unusual situations, such as around jet aircraft, but what of its' possibilities for more normal use?

Several criteria may be used to compare skin communication to audition. First, it is possible to look at the difference in training time. Subjects with the mechanical vibration system discussed earlier achieved a reception rate of 38 words per minute with a training time measured in days, while a similar level with Morse Code would require weeks of training. The Army, incidentally, considers a man proficient in Morse at a rate of about 18 to 20 words per minute. It is obvious, however, that Morse Code is grossly inefficient, for we can understand speech at a rate of some 250 words per minute. Can we approach such a rate for skin communication? Some increase in speed over the present rate is no doubt desirable, and a

likely candidate for such an increase is to use some sort of phoneme system.

It has been suggested that the best use of cutaneous signals at present would be for some sort of "warning" or "alerting" purpose. A comparison of skin vs. auditory information of this type would entail a vigilance study, now in progress, in cooperation with Dr. Loeb, head of our Audition Branch.

At this time, I make no prediction that the skin will displace the eye or the ear as a primary channel one uses to receive information. On the other hand, it is possible that we may yet win the "SKIN GAME."

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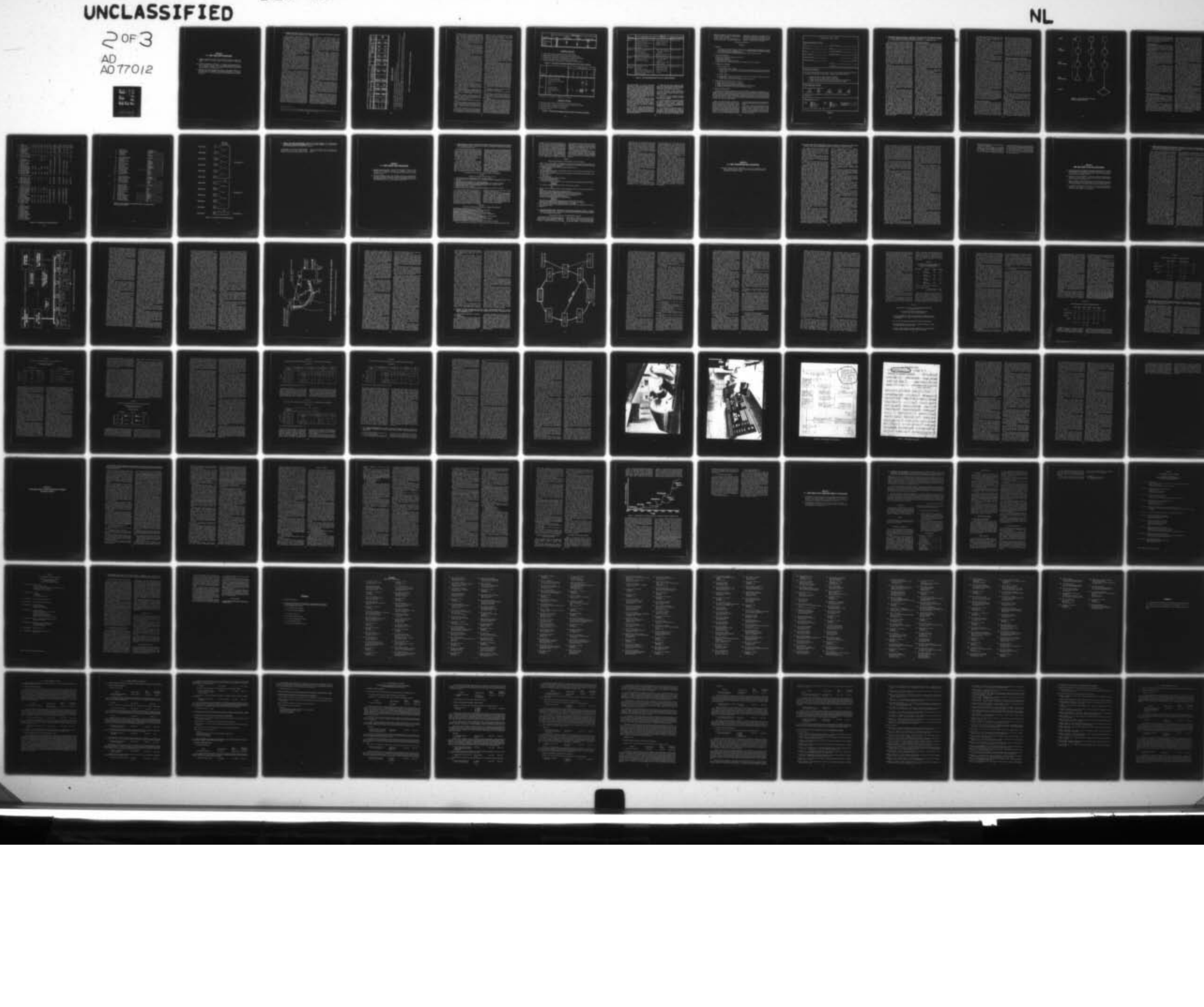

CHAPTER 6
U. S. ARMY SIGNAL CORPS PRESENTATIONS

A. HUMAN FACTORS IN THE EVALUATION OF SIGNAL CORPS SYSTEMS: Edward W. Bishop; Dunlap and Associates, Inc., Stamford, Conn.

B. SYSTEMS DEMANDS ANALYSIS: A Method for Specifying Procedures: Donald H. Armsby; Applied Psychology Corporation, Arlington, Va.; and Daniel L. Heubner, U. S. Army Signal Research and Development Laboratory, Ft. Monmouth, N. J.

C. HUMAN FACTORS ENGINEERING ASPECTS IN DEVELOPMENT OF SPECIALIZED ELECTRONIC WARFARE EQUIPMENT: Lt Colonel R. D. Speers, U. S. Army Electronic Proving Ground, Fort Hauchuca, Arizona.

A. HUMAN FACTORS IN THE EVALUATION OF SIGNAL CORPS SYSTEMS BY Edward W. Bishop, Dunlap and Associates, Inc., Stamford, Conn.

This morning I would like to discuss a problem which is encountered in the day-to-day application of human factors. This problem arises as a question: "How can the human factors specialist support the evaluation required in the normal course of equipment development?" We have worked jointly with the Signal Corps at Fort Monmouth in the development of several equipments by providing support to their in-service human factors effort. We have in general acted as consultants to the equipment engineers.

When equipment is ready for testing, we have been requested to help the engineers insure that the human factors are accounted for in the test program.

In this paper I will discuss the approach we have evolved and the specific guidance we have given to the engineers. We have adopted a viewpoint that each equipment and the operator (or operators) required to man it comprise a system. This implies that the equipment and men together are required to accomplish certain goals or requirements and that they constitute a functional entity. This provides a frame of reference that permits evaluation of the equipment in terms of its ultimate use rather than in terms of what it can do.

To illustrate: a radar intended for battlefield surveillance may--because of the state-of-the-art--be capable of locating and discriminating targets as small as individual troops. However, the system user (e.g., the battlefield commander) may require only the knowledge that there are moving objects at a given location and that the objects are of some gross category (e.g., men or vehicles). The fact that the equipment is capable of precision beyond present needs is of interest for future development and application; but the immediate evaluation must be based on the present system requirements. At this point, one may say it is easy to be glib about system goals and evaluation in terms of these goals, but that in practice it is usually difficult to identify them. This difficulty is very real, and usually arises because either the system user doesn't have a clearly established need or the capability of new equipment is unknown and thus difficult to relate to the user's needs.

Our proposed approach to overcoming this difficulty consists of a systematic development of goals with the user as a first step in system evaluation. This is opposed to an approach in which goals are sought from an external source. The important part of that last sentence is the word "sought." The difference in approach which I wish to emphasize is the difference between developing goals as an active human factors function and passively asking, "What are the system goals?" The human factors specialist cannot limit his interest to determining how well a man-machine combination can do some specified job; he must consider also the human factors in the job to be done, i.e., the goal of the system.

In preparing this paper, I reviewed the previous conference reports and found that, as one would expect, there has alway been an awareness of the importance of the user's needs. Usually this has been expressed in some way that indicates the user would provide information about goals on request -- the human factors specialist need only request. Unfortunately, our experience has been that often the user states his needs in a format that is too general to be useful or that the needs are, as I noted earlier, simply not established. The function of the human factors specialist is then to help the user establish and express his needs as goals for the system. To implement this approach, we undertook a study[1] to outline the steps necessary to identify the human factors goals and to evaluate for them. The purpose of the study was to provide guidance for engineers in their development of a test plan. We described the steps and illustrated them by an assumed application to ground surveillance radars. I will now describe these steps and the illustration.

The initial step in this development is to examine the concept and utilization of ground surveillance radars. This was accomplished (in our study) jointly by human factors and Signal Corps operational personnel. The role of human factors in this step was to provide information about human performance and thus direct the examination toward those aspects of the radar system pertinent to the operators.

The concept underlying ground surveillance radars was determined to be that they will supplement or replace visual contact and that they will do this by extending the range of contact and by providing contact under adverse conditions. A radar might also provide greater reliability and accuracy than a man making a visual sighting. This, in general, is the mission of the system. To make this

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[1]Bishop, Abbott, Bowen and Channell, A Methodology for the Evaluation of Ground Surveillance Radars, Final Report on Signal Corps Contract No. DA-36-039-SC-73253, Task Order .02, Stamford, Conn., June 1959

Target motion		"Ideal" (corner reflector)	Single man		Groups of men				Vehicles					Special	
					10 or less		11 or more					Aircraft			
Direction	Speed		U*	C*	U	C	U	C	Jeep	Truck	Tank	Fixed wing	Rotary wing	Beacon	Mortar
Radial to observer	Slow	4	2	1	3	1	2	0	2	3	2	1	1	2	
	Med.	4	4	3	4	2	3	1	3	3	3	3	3	3	
	Fast	4	2	1	3	1	2	0	2	3	2	1	1	2	
Lateral to observer	Slow	4	2	1	3	1	2	0	2	3	2	1	1	2	2
	Med.	4	4	3	4	2	3	1	3	3	3	3	3	3	
	Fast	4	2	1	3	1	2	0	2	3	2	1	1	2	

*U - Upright, C - Crawl.

PRIORITY SCALE

4. Target very significant; essential to investigate fully.
3. Target important; essential to gain at least limited information.
2. Target moderately important; investigation normally indicated especially when data from priority 3 and 4 targets are not sufficiently relevant.
1. Target of slight importance; investigate only if time is available and other target data are not relevant.
0. Target is generally of negligible significance; may be important as a special case which occurs infrequently.

Figure 1. Selecting and Assigning Priorities to Target Variables

statement useful as a criterion in evaluation, it is necessary to elaborate upon those aspects which affect implementation of this concept. Further examination suggested that there are three important aspects: the physical environment in which the system is to operate, the nature of the targets to be sought, and the nature of the tasks to be performed by the operator.

Each of these aspects was next further detailed. The environment and target characteristics were specified by the operational personnel. The nature of the operator's tasks was defined by the human factors personnel based on the stated operational needs. We will look at these details in a moment, but I should first like to describe the next step of our development.

Our joint effort has thus far yielded a picture of the total possible system operation -- environment, targets, and operator tasks. As you might expect, this presented a range of possibilities that are not all of equal importance to the system user. In fact, some of the combinations would be so rare as to be nearly impossible. Our next step was, therefore, to submit these possibilities to a review for importance by operational personnel. The human factors role in this review was twofold: first, the methodology of rating importance had to be properly employed and this, of course, is a basic tool of human factors research. Second, the operator's tasks must be properly represented to the rater. Guidance in these two areas, then, was the human factors contribution. We will now see the system characteristics as they would be rated. The ratings are shown in three slides, one each for target, environment and equipment variables. The values are illustrative, not actual. (Figures 1, 2, and 3.)

We had identified the operator tasks as being to detect, identify, locate and track targets. These tasks were defined as follows:

1. Target detection - Perception by the operator of a return.
2. Target identification - Apprehension by the operator of those target characteristics which are distinguished by the radar, and which serve to differentiate classes of targets.
3. Target location - Determination by the operator of the position of the target with reference either to the equipment or to an arbitrary reference base.
4. Target tracking - Continuous target location.

A final task would be target contact termination - Determination by the operator that contact with the target is ended or interrupted. (Essentially this is the converse of item 1.)

(The above listing, of course, does not include all the tasks which could be assigned to the operator. He may also be involved in the transportation, setup and orientation of the equipment, and his performance of these tasks is subject to evaluation. This study, however, was limited in scope to operation of ground surveillance radar.)

It became apparent in attempting to rank these tasks that missions for specific radar applications would be involved. Therefore, for this development of a generalized guidance, the tasks were assumed to be of equal importance and each task was assumed to be a possible mission for a radar system. Our next step was to relate these tasks to the other variables that had already been ranked as to importance. This was accomplished by defining the criteria for evaluation to be used for each task. These criteria establish the measures to be taken under each combination of variables previously rated important. The measures are of two kinds: objective performance measures and the subjective evaluation of performance by an observer skilled in radar system operation. These criteria are shown in Figure 4.

(The opinions are included as a means for drawing on the knowledge of skilled personnel usually available to an equipment test program, and for obtaining some estimate of qualitative aspects of performance. Also, in view of the limited time usually assigned for evaluation, such opinions might have to be used more than would otherwise be desirable.)

To this point the evaluation program consisted of the measures to be taken and conditions under which they would be taken. The next step was to consider the techniques (or experimental designs) for testing that would assure adequate consideration of the selected variables. This was approached from the position that the design selected for evaluation should yield information that would be usable in reaching decisions about the equipment. The information yielded by the study, therefore, must have the following characteristics:

1. Objectivity, or the absence of personal bias.
2. Reliability, which is confidence that the information is not variable.
3. Accuracy, or the absence of constant error.
4. Validity, or the extent to which the information describes the desired measure.
5. Relevance, or the pertinence of the information to the decision to be made about the system.
6. Completeness, or the condition that the information contains all of the relevant data.

There are, of course, several experimental designs which will produce results having these characteristics. The selection of a design then hinges on the satisfaction of the demands imposed by the limits of resources and the need to evaluate under certain selected variable conditions. To the human factors specialist, this suggests an experimental design of the incomplete factorial type. However, this plan was being developed for other

Vegetation	Land-form: Flat	Hilly undulating	Hilly broken	Mountainous
Bare	4	1	1	3
Agricultural	2	2	2	0
Brush	2	2	2	0
Wooded	3	1	1	2

PRIORITY SCALE

4. Very important; essential to investigate fully.
3. Important; should gain at least limited information.
2. Moderately important; investigation normally indicated.
1. Least important; other data probably relevant.
0. Unlikely situation; generally of negligible significance.

Figure 2. Selecting and Assigning Priorities to the Environment Variables

Antenna mode	Signal comparison mode	Display mode: A Scope	B Scope	Aural	A + Aural	B + Aural	A + B	A+B+Aural
Auto.	Normal video (N)	0	1	0	0			
	Coherent MTI (C)					2D		
	Non-coherent MTI (NC)				3D			
	N+C					4D		
	N+NC				2D			
Manual	Normal video							
	Coherent MTI	2L	2L	2L	4I3D	4T		4L
	Non-coherent MTI	2L		2L	3LIT			
	N+C							
	N+NC							

D - detect, L - locate, I - identify, T - track.

PRIORITY SCALE

4. Primary mode for which equipment designed must be tested.
3. Secondary mode; should be investigated as an alternative scheme.
2. Possible mode; investigate if time permits.
1. Possible mode; not worth investigating.
0. Impossible mode.

Figure 3. Selecting and Assigning Priorities to Mode of Operation Variables

Mission	Measure		
	Accuracy	Speed	Observer opinion
Detect	Ratio of targets detected to targets present. Number (or proportion) of absolute errors. Direction of absolute errors.	Time from onset of target to detection. Range at which detection occurs.	Ease of task.
Identify	Number (or proportion) of absolute errors: of all targets. of a class of targets. Direction of errors.	Time from detection of target to identification. Range at which identification occurs.	Ease of task.
Locate	Number (or proportion) of absolute errors. Direction of errors.	Time from identification of target to location. Range at which location occurs.	Ease of task.
Track and dispose	Coordinate error in tracking. Direction of error. Correctness of disposition. Ratio of time off-track to time on-track.	Time required to establish tracking. Ratio of time off-track to time on-track.	Ease of task.

Figure 4. Selecting Measurement Criteria for System Missions

than HF personnel. So, a set of rules was developed to direct the design of a test program. These rules were developed to provide guidance for an experienced equipment engineer in organizing the operator's tasks and the selected variable conditions into a manageable evaluation plan. Remember that the rules apply to the conditions already selected as being important and that the rules will be used to include as many highly rated conditions as possible in the tests.

1. When it is possible to study more than one set of conditions, they should be chosen such that the widest range possible is encompassed. For example, the "best," "poorest" and "average" of a condition should be studied rather than only those conditions near the "best."

2. Choose for study those effects which are very likely to have similar influences upon a variety of conditions as shown in the ratings rather than those effects which have unique and different influences dependent on the conditions studied.

3. Make sure that events chosen for study which are unique and do not afford much possibility for generalization are the most important factors in system performance.

4. Give preference to the conducting of tests that will yield a large amount of information in a given interval of time by combining variables.

5. Whenever a strict comparison between two items is required, all other variables should be held constant.

6. Every measurement is relatively useful or useless according to how well it satisfies the quality criteria, namely: objectivity, reliability, accuracy, validity, relevance, and completeness. Therefore, assess each measurement by these criteria.

7. It is desirable to consider the form of the results when selecting the design for evaluation. The data themselves, or the way in which they are to be used, will often dictate the form in which they should appear (e.g.,

tabulated, graphed or charted). Knowing this, the test designer can select a technique which is most suited to that form.

After these rules have been applied, an evaluation program is available that permits performance measures to be obtained under important representative conditions. In our example we outlined four tests that would be developed by application of the suggested procedure. I will describe one of these.

TEST PLAN EXAMPLE

Test No. 1

A. Purpose:

1. To evaluate the system capability precisely for a limited number of targets in an ideal environment while the equipment is used in its theoretically best mode of operation; and to study the effects of target motion.
2. To evaluate the ease of performing the primary missions of the system.

B. General Test Design:

Four-way factorial with replication as follows:
4 target type conditions
3 target speed conditions
2 target direction of motion conditions
2 operators giving 5 observations of each combination of other conditions.

C. Conditions to be Studied:

1. Invariant conditions
   a. Environment - bare and flat.
   b. Mode of operation - automatic and manual scan as required; non-coherent MTI and normal video as required; A scope, B scope, and aural presentation of target data as required.
2. Variable conditions
   a. Target types - corner reflector, single upright man, group of 10 upright men, truck.
   b. Target speed - slow, medium, fast.
   c. Target direction of motion - radial and lateral to observer.

D. Measurements Taken (Illustrated in Figure 5)

1. Range and time at which target is detected.
2. Range and time at which target is identified.
3. Range, azimuth and time when location of target is determined.
4. Length of time between detecting and disposing of target.

E. General Conduct of Test

Single targets are placed successively at random outside the range of the equipment. For radial motion the targets approach the radar until they are detected. For lateral motion a number of targets are placed at decreasing ranges and successively cross in front of the radar until the operator detects and identifies them. The operator continues to track the target until the required number of range and azimuth readings have been taken. The test observer will evaluate the ease and skill with which the operator performs his tasks and other pertinent data as well as the prevailing weather.

When a test like the above has been completed, a reasonably complete picture of system performance will be available. In this picture some account will have been taken of all the conditions which would affect actual performance. The human factor role has been to provide guidance about operator behavior and about the methodology for measuring that behavior. The important aspect of the role is that it is active in establishing the nature of the evaluation program and not passive in examining a limited area of specialized interest.

The study I have described to you is now being used by the Proving Grounds at Fort Huachuca, and we hope in the future to have reports of their experience with it. In the meantime, we hope to have stimulated thinking about the relationship of human factors to system evaluation.

OBSERVER'S TEST FORM

IDENTIFICATION OF TEST

Date ______	Target Type(s) ______
Test No. ______	Speed ______
Time ______	Direction of Motion ______
Site Location ______	Equipment Mode ______ scan
Operator Name ______	______ MTI
Observer Name ______	______ display
	Terrain ______
	Vegetation ______

RESULTS OF TRIALS

The kind of information to be recorded in this section will depend upon the exact requirements of the users of the data. Typical recordings would be:

1. Range and time at which target is detected.
2. Range and time at which target is identified.
3. Range, azimuth and time when location of target is determined.
4. Length of time between detecting and disposing of target.

PERFORMANCE RATING

Subject performed (check one)

☐ Excellent ☐ Well ☐ Acceptable ☐ Poorly ☐ Badly

Comment on any significant or unusual features of trials or subject's performance.

WEATHER (check one)

Wind		Rain			
	☐ weak		☐ nil	Temperature	______ F°
	☐ moderate		☐ moderate	Pressure	______ in.
	☐ strong		☐ heavy		

Comments on weather (fog, snow, etc.)

Figure 5.

B. SYSTEMS DEMANDS ANALYSIS: A METHOD FOR SPECIFYING PROCEDURES by Donald H. Armsby, Applied Psychology Corporation, Arlington, Va., and Daniel L. Huebner, U. S. Army Signal Research and Development Laboratory, Ft. Monmouth, Md.

This report deals principally with the concepts and methods formulated during the first phase of a multiphase project. Its goal is to develop for and provide to the engineering psychologist members of Signal Corps system design teams, tools and data which have not so far been available to them. The major reason for undertaking this project is to improve, systematize, and objectify the tools of engineering psychologists so that these specialists can increase their aid in the design of maximally effective systems. The project is concerned with the design of future systems as these systems affect the performance characteristics of operators in the man-machine interface. Emphasis is placed on the inclusion of human engineers in the earliest design stages and the effective establishment of a sytems-oriented team approach to design.

Although the project proposes to provide tools and data which will eliminate many of the chance factors in designing new systems, the first phase was necessarily focused upon specifying exactly the operations performed with present systems. This information was not available at the outset of the project nor was there any acceptable way of obtaining it. Terminology was, and to some extent still is, especially confusing. Investigators use different sets of data, which makes it almost impossible to generalize from their findings. The reason for starting with an analysis of present operations is that detailed knowledge of these operations will form the base from which ineffective, wasteful, and overlapping operations may be corrected during early design stages, substituting for them standard tasks which accomplish the same purpose more effectively.

The first phase of the project has been accomplished. Methods have been formulated to specify and define present operations. Units of operator behavior have been defined by the determinants of that behavior. These determinants, which we have called demands, are made more explicit by adding qualitative and quantitative dimensions and are tied in to concrete specifications. Demands have been grouped into categories, and the simultaneous occurrence of many demands defines an operation. Operation limits have been established and a form for presenting an operation taken out of context has been developed. Finally, a method has been developed for relating and grouping operations so that they constitute the next larger behavior unit, a procedure. Although this first phase of the project is seen principally as providing a basis for further research, some immediately useful findings have resulted which will be discussed later.

Procedure for Analysis

Current practices in "task analysis" go either too far or not far enough for the objectives of this project. The terms presently used are generally concerned with psychophysical details (for example, Flicker below threshold, or Reaction time) or, on the other hand, with gross behavior (for example, Scan or Manipulate). In the case of minute details, there is no means by which grouping can be easily accomplished; and statements such as Scan are so broad that it is not possible to know specifically what the operator is doing. There are tendencies to focus upon observable physical movements or to make inferences about complex mental activities. The uncritical use of task terms makes it difficult to determine when, where, and why one task ends and another begins and makes it almost impossible to determine essential similarities and differences between tasks, especially when they are performed with different types of equipment.

After considering these difficulties, a method of task analysis was developed which avoids most of these difficulties.

Since no standard terminology presently exists, we have taken some words which seemed appropriate to the purpose and have assigned quite specific and specialized meanings to them. The four major terms we are concerned with in this phase are Demands, Dimensions, Operations, and Procedures. The particular sense in which they are used in our system will become apparent as each is examined in detail. This analysis method is a means by which a functional behavioral unit can be broken down into those related elements of the over-all situation which demand that a monitoring type of behavior must occur. In our approach, since we do not know in advance what a monitoring type of behavior is, we start by analyzing many types of operations and then assign the term "monitoring" to one of these types.

As we have said, the determinants are called demands. A single demand is defined as the requirement which a particular aspect of the man-machine's total relationship places upon the operator so as to limit, prescribe, or allow certain activities on his part so that he may successfully accomplish his purpose. Any single demand may change for every behavioral unit with which it is associated; or it may be constant for several units of behavior; or it may be constant for all the operations. (The term "behavioral unit" is used here rather than "task" because of the special sense in which we will use the word "task".) In arranging levels of abstraction, the demands are such that they occur at a more abstract level than

psychophysical details and at a more concrete level than general task descriptions. One capability of the analysis method is in connecting all three levels.

At present we have identified fifty-two demands, the presence, absence, type and/or intensity of which have an effect upon the operator's behavior in the performance of his duty. Insofar as possible, these demands were selected to include all the major determinants of an operator's behavior and to meet two additional criteria: to state the demands in such a way as to allow the operator to be either a man or a machine, and to limit the demands to those responsive to alteration by changes in design.

Each demand has a dimension, the nature of which depends on the demand's characteristic, and it is these "qualifying" dimensions which give us the "degree" of what is demanded of the operator.

A few of the demand dimensions consist of a "yes" or "no" statement and some have to do with types, while most are an approximate scale of intensity. The demand "type of signal input" is an example of a demand whose dimensions are types. The types of signal input so far considered are: indicators, scales, alphanumerical material, energy signs (such as infra-red), symbols (such as radar), plots and maps, photos, and structured enhancement. This last type includes such things as time compression and color coding and is used in conjunction with the other types. These signal types are subgrouped so that the first three are digital symbols and the other six are analogic, and all are arranged in an ordinal scale of message completeness. In the analysis process, each demand is used in association with the dimension appropriate to the particular situation. To illustrate, the demand "resolution" would be used in association with one of its dimensions ("high," "medium," or "low"), the two together constituting the unit of analysis.

Many demands are analyzed further to relate them to more concrete details which we shall call specifications; some examples are: foot-candles, height-width ratio of symbols, diameters of knobs, etc. These specifications are being collected in two forms: the physical aspect, and the optimal range of that physical aspect in regard to a human operator.

Categorizing of Demands

For use as an analytic tool, we have divided the fifty-two demands into five categories: input, data-sensing, data-processing, data-generating, and output. They are grouped in this way partly for analytic convenience and partly to indicate a time and action sequence, but mainly to indicate something of their functional interrelationships. Demands in the input category are concerned with two types of input: those from outside the system and those generated by the system itself. Demands in the data-sensing, data-processing, and data-generating categories form an internal system like a cascading integration; i.e., after data about the input are sensed, the operator performs an operation with the data and, depending upon the quantitative and qualitative adequacy of the data, generates new, better, or more inputs. Through time, a series of events forms a closed loop of related inputs and sub-outputs until no further change (or in this case, output to the user) occurs. The data-generating demands are concerned only with the generation of data for the use of the operator, not directly for the eventual user. The output demands are concerned with the data intended for the user.

Simultaneous Occurrence of Demands

After the demands' dimensions have been established, the specific dimensions which occur in a particular system at any given time must be combined and related. The dimension of every demand applicable to the functioning of a system is noted as the demands occur simultaneously or in a related sequential arrangement. Based on the previous steps, the resulting structure of an operation consists of four and only four of the five demand categories.

Figure 1. illustrates the three possible groupings of demand categories. Two are those in which input demands occur, followed by or simultaneously occurring with data-sensing demands, data-processing demands, and data-generating demands. In one of these two forms the sub-output from the data-generation is such that it produces no immediate new or altered input. This is similar to programming a computer. In the second, more usual form, the sub output from data generation does feed back and leads to immediate new or altered inputs and best fits the model of a closed loop cascading integration. (It may well be that the number and extent of such operations could be used to reflect the complexity of systems' functioning.)

The third form of demand category grouping occurs either with very simple systems or as the final operation of complex systems. It consists of input, followed by data-sensing, followed by data-processing, which is followed by output.

Regardless of the form involved, the total of all the demands' dimensions occurring simultaneously is taken to be the definition of the operator's behavior at that time. Although some of the demands are concerned directly with physical movement (examples are: force required, and degree of coordination), the total demands situation is the smallest unit of behavior we are treating independently. This is what we term an operation. Thus, the specific dimensions of as many as forty demands (using four of the five categories) taken together define the

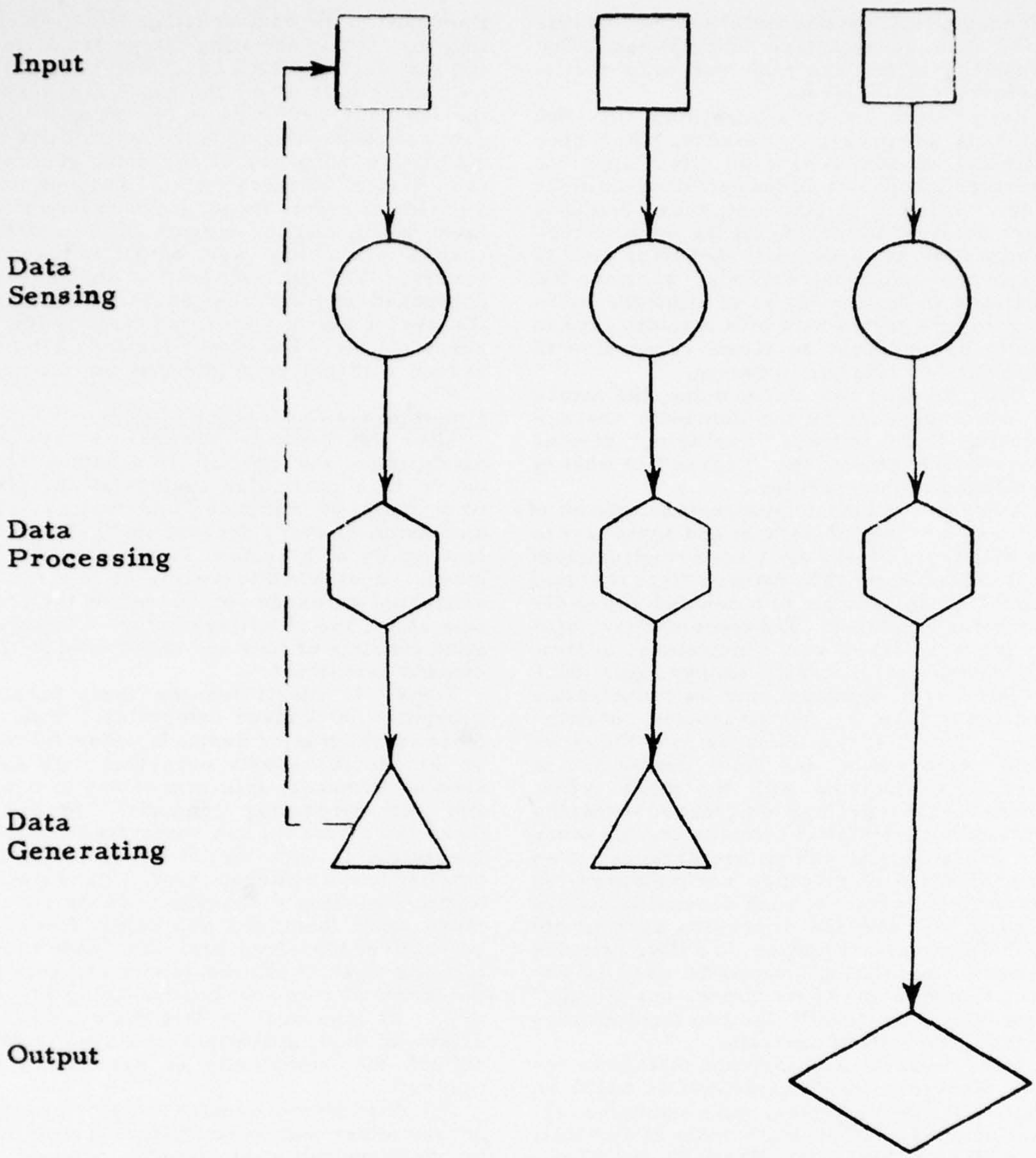

Figure 1. The Three Patterns in which Demand Categories Occur

operation demanded by the total situation. Or, presented in another way, each operation consists of as many as forty demands' dimensions occurring simultaneously or in closely related sequence.

Operational Limits

Since operations are considered the basic building blocks of behavior, it is necessary next to determine their limits and to find how a single operation can be lifted out of context and presented to give a concise yet complete description of it.

It was decided to define operation limits by the change of one or more of the demands. (Change is defined as any of the following: when a demand becomes no longer applicable; or when a demand not applicable to one operation becomes applicable to the next; or where one demand dimension shifts to another dimension in the next operation.) Where one or more demand changes occur, then a change in content of an operation occurs and a new operation begins.

The importance of developing a form effectively to represent a single operation stems from the fact that operations as defined and developed here must be amenable to being used as units in different contexts. Figure 2. presents an example of an operation matrix constructed for this purpose. Up to this point our matrix describes all the operations of a system. Each vertical column of the matrix could be used to define an operation at that particular point in the system. However, examination of the matrix shows that several of the demands do not change at each operation limit and therefore, if we extract a column from the matrix we omit valuable information about the continuation of demands from one operation to the next. Therefore, to present an operation we show the central column containing the demands' dimensions which are occurring at that time, plus wing additions to the right and left of the column for all continuing demands. This method of presentation is shown in Figure 3.

Grouping of Operations

The next step is to determine how operations may be grouped into the next larger unit of behavior, the procedure. It was suggested that a procedure be defined as a group of related operations; the difficulty lay in determining how operations may be considered "related."

A method of "key demands" analysis was eventually formulated. This analytic method recognized that there is a considerable difference in the total number of demands changing between different operations. Between some, only a few demands changed. These changes appeared to be of minor significance, both in number and type. Between other operations there appeared to be a major change, both in numbers and importance of the demands. The significance is that certain of the demands, when they change, appear to key off changes in many other demands; they therefore appear to be the "key" demands of that system. It was thus decided that changes in key demands best express the relatedness of operations. As long as key demands do not change, operations changing during this time may be grouped together as a procedure. Procedure limits are therefore determined by changes in key demands, since such a change in key demands appears to be the point at which one procedure ends and another begins, as illustrated in Figure 4. A procedure could be composed of any number of operations, from one upwards, and a complete function could be composed of only one procedure which in turn could be composed of a single operation.

We believe that several practical applications will result from this research when it has been concluded. We feel that the first phase has already provided a means for cataloging equipments and the procedures currently used with them. By assigning terms to specified procedures we have a good basis for a standard terminology. Giving a value to each of the demands' dimensions makes it possible to produce a procedure difficulty measure which, even though approximate, we believe is fairly accurate. Progress has been made toward solving what has sometimes been called the partitioning problem. This is the problem of determining how to extract and analyze segments of a system without interfering with interrelationships after the system is reassembled. The specification of procedures provides a means for predicting positive transfer of training.

The next phase of research will deal with converting specified procedures into standard tasks. The following phase will further refine standard tasks as these tasks are affected by system criteria and requirements.

In skeleton form, and as a restatement: We describe a method for procedure analysis by first determining the demands imposed upon the operator (we have attempted to delineate those demands especially applicable to Signal Corps surveillance systems); we have analyzed the demands in terms of those qualifications of type and intensity which apply to each; and we call these "qualifiers" Dimensions; through changes in demands or their dimensions, we identify, describe and limit Operations; and by noting changes in Key demands, we identify Procedures. In subsequent activity, we will build on the work already done in an effort to establish an effective means of standardizing Tasks.

		Input	1	2	3	4	5	6	7	8	9	10	11	12
I	1	Type signal	D3	D3	A 5	A2	D3	D3	A2	A2/D2	A2/D2	A1	A1	A3/D3
	2	Figure/ground	H	H	H	H	H	H	M	M/H	M/H	H	H	H
	3	Signal/noise							L	L	L	H	H	
	4	Definition	H	H	M	M	H	H	L	L/M	L/M	H	H	H
	5	Resolution							M	M	M			
		Data Sensing												
II	1	Msg. type recd.	S	S	S	S	S	S	P	P	P	A	A	P
	2	Collateral intel.				2rs	lic			2rs im	2rs im			2r
	3	Similarity	L	L	L	H	L	L	H	H	H			
	4	Discriminability				H			M	M	M	H	H	H
	5	Duration							M	M	M	M	M	
	6	Rate of change							M	M	M	M	M	
	7	Simult. msgs.							H	H	H	L	L	
	8	Frequency							M	M	M	M	M	
	9	Spatial location	C	C		M	C	C	P	P	P	P	P	
	10	Spatial interval	M	M		M	M	M	S	S	S	S	S	
	11	No. poss. kinds	2	2	M	2	2	2	2	2	2	2	2	
	12	Predictability							H	H	H	M		
	13	% action msgs.							M	M	M	H	H	
	14	Amount attention	M	M	M	M	M	M	H	H	H	H	H	
	15	Fixation area	M	M	L	M	M	M	S	S	S	S	S	S
		Data Processing												
III	1	Type msg. used	I	I	A	S	I	I	A	A/S	A/S	S	I	A
	2	Type data trans.	1	1	1	1	1	1	3i	3p	3p	3p	1	3r
	3	Degree precision			L	L				M	M	H	H	H
	4	Action time lag							B	B	B	B	B	B
	5	Speed processing							R	R	R	R	R	R
	6	No. alternatives							N	N	N	N	N	M
		Data Generating												
IV	1	Type of control	1	1	2	2	1	2	2	2	2	2	1	
	2	Coding of control	No	No			No						No	
	3	Contr-occurrence	M	M	M	M	M	M	No	No	No	No	No	
	4	Control-quality							S	S	S	S	No	
	5	Contr-repetition	M	M	M	M	M	M	No	No	No	No	No	
	6	Control-rate							No	No	No	No	No	
	7	Control-duration							No	No	No	No	No	
	8	Sensitivity	G	G	G	M	G	G	G	M	M	F	G	
	9	Manipulation	D1	D1	C	C	D1	D1	D1	C	C	C	D1	
	10	Deg. coordination				M			M	M	M	M	M	
	11	Force required	L	L	L	L	L	L	L	L	L	L	L	
	12	Location control	C	C	C	C	C	C	C	C	C	C	C	
	13	Results avail.	Y	Y	Y	Y	Y	Y	No	Y	Y	Y	Y	
	14	Correc. poss.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	No	
		Output												
V	1	Type msg. sent.												S
	2	Commo. instru.												Tp
	3	Control-occurr.												S
	4	Duration												B
	5	Speed required												M
	6	Frequency/hr												M
	7	Control-quality												M
	8	Output repeatable												Y
	9	Results avail.												No
	10	Correc. poss.												No
	11	Error seriousness												H
	12	Error allowable												L

Figure 2. An Example of an Operation Matrix

I	1	Signal type	symbols
	2	Figure/ground	medium
	3	Signal/noise	low
	4	Definition	low
	5	Resolution	medium
II	1	Msg. type received	primary
	2	Collateral intell.	
	3	Similarity	high
	4	Discriminability	medium
	5	Duration	medium
	6	Rate of change	medium
	7	No. simult. msg.	high
	8	Frequency	medium
	9	Spatial location	peripheral
	10	Spatial interval	small
	11	No. poss. kinds	two
	12	Predictability	high
	13	% action msgs.	medium
	14	Amount attention	high
	15	Fixation area	small
III	1	Type msg. used	analogic
	2	Type transformation	interpret
	3	Degree precision	
	4	Action time lag	brief
	5	Processing speed	rapid
	6	No. alternatives	none
IV	1	Type of control	handwheel
	2	Coding control	
	3	Control-occurrence	no
	4	Control-quality	some
	5	Control-repetition	no
	6	Control-rate	no
	7	Control-duration	no
	8	Sensitivity	gross
	9	Manipulation	discrete
	10	Degree coordination	medium
	11	Force required	little
	12	Control location	control
	13	Results available	no
	14	Correction possible	yes

Figure 3. One Column from an Operation Matrix, Showing Present and Continuing Demands

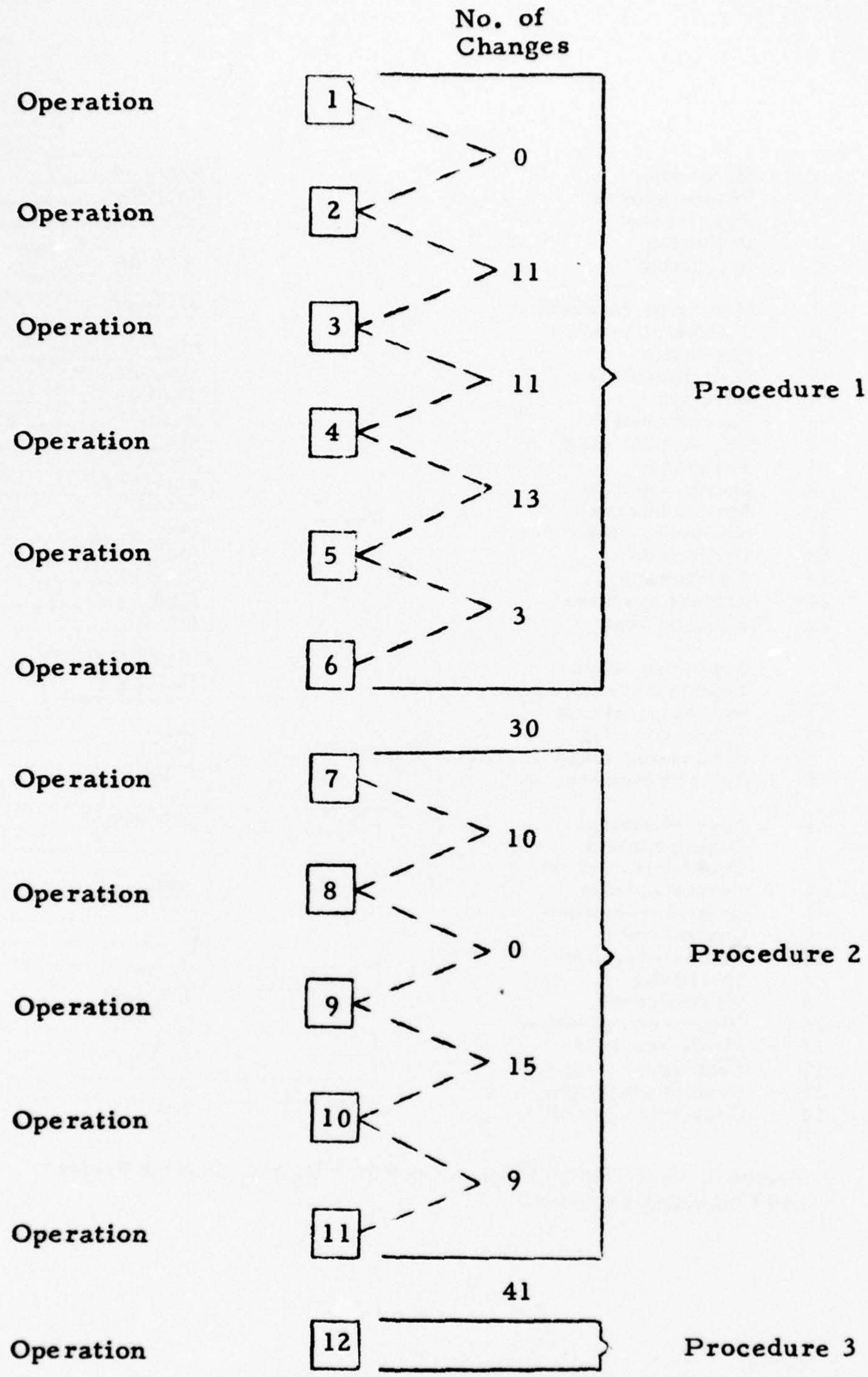

Figure 4. An Example of Grouped Operations

C. **HUMAN FACTORS ENGINEERING ASPECTS IN DEVELOPMENT OF SPECIALIZED ELECTRONIC WARFARE EQUIPMENT** by Lt Colonel R. D. Speer, U. S. Army Electronic Proving Ground, Fort Hauchuca, Arizona

This paper is classified "FOR OFFICIAL USE ONLY" and is on file with the Human Factors Research Division, Office of the Chief of Research and Development, Department of the Army, Washington 25, D. C.

CHAPTER 7
U. S. ARMY CHEMICAL CORPS PRESENTATIONS

A. DISSEMINATING HUMAN FACTORS ENGINEERING INFORMATION WITHIN THE CHEMICAL CORPS: Dr. Leonard C. Meade, Tufts University, Consultant to the Engineering Command, U.S. Army Chemical Corps.

B. PSYCHOPHARMACOLOGY AND HUMAN FACTORS ENGINEERING IN THE U.S. ARMY CHEMICAL CORPS (Unclassified Abstract of a CONFIDENTIAL Paper): Dr. Earl Davy, Chief, Psychology and Human Engineering Branch, U. S. Army Chemical Center, Md.

A. DISSEMINATING HUMAN FACTORS ENGINEERING INFORMATION WITHIN THE CHEMICAL CORPS by Leonard C. Mead, Tufts University, Consultant to Engineering Command, U. S. Army Chemical Corps.

The speaker was asked to serve as a Consultant to the Engineering Command several years ago as a result of the then Commanding Officer, Colonel Allen, attending one of the earlier Army Human Factors Engineering Conferences. Colonel Allen asked his new consultant the following two questions:

1. Were there human factors engineering problems within his Command, and
2. If so, how should they be met.

The speaker initiated a series of visits to the Army Chemical Center and spent considerable time interviewing project engineers and administrators who were familiar with the overall program. After a period of several months, it was decided that the answer to the first question was that there were human factors problems both in certain end-items for use by the individual soldier and in the production line set-ups and procedures for certain Chemical Corps products. In order to answer the second question, it was decided to set up a program to "sensitize" project engineers in particular, as well as other Chemical Corps personnel, about the nature and uses of human engineering so that these individuals would consult the appropriate literature in the field or else seek out human factors engineers when faced with a man-machine problem for help.

In 1958 the speaker arranged a series of indoctrination seminars to be conducted at Edgewood. The mission of these seminars was to establish "appreciation" for human factor considerations among selected project engineers in the Engineering Command, the Materiel Command, and the Research and Development Command.

The following table gives the schedule of topics and speakers

TABLE 1

Program of Indoctrination Seminars in 1958

1. Introduction to Human Engineering by Dr. Leonard C. Mead.
2. The Presentation of Information and the Design of Controls for Human Use by Dr. Jesse Orlansky.
3. Effeciency of Performance by Dr. Robert B. Sleight.
4. Methods and Their Application in Human Engineering by Dr. Alphonse Chapanis.
5. Human Engineering and the Evaluation of Equipment by Dr. Jerome H. Ely.
6. Anthropometry by Mr. Wilbert K. Carter.
7. Work by Dr. Francis N. Craig.
8. Environmental Factors Affecting Human Performance by Dr. Warren Teichner.

In order to assess whether the mission of the seminars had been accomplished, a follow-up questionnaire was administered to the participants asking their reactions to the seminar contents, delivery, schedule of presentation and overall opinions concerning their usefulness. Without going into the details of the opinions received we came to the conclusion that a reasonable amount of acceptance of the notion of human factors engineering was generated on the part of the participating project engineers. A common comment, however, was that their supervisors were not convinced.

Beginning in 1959 the Chief Psychologist of the Army's Research and Development Command initiated a program of circuit seminars (patterned to some extent on the series conducted at Edgewood) to be conducted at six or seven of the Army's (Technical Services). The following table is an outline of the circuit seminar series conducted by Dunlap & Associates.

TABLE 2

Program of Army Circuit Seminars by Dunlap and Associates

Introduction to Course by Dr. Jesse Orlansky.
Scope of Human Factors Engineering by Mr. Joseph G. Wohl.
Design for Maintainability by Mr. Joseph G. Wohl.
Workplace Layout and Body Size by Mr. Robert T. Eckenrode.
Effect of Environment on Performance by Mr. Robert T. Eckenrode.
Man-Machine Dynamics by Dr. Jerome H. Ely.
Man's Output Characteristics and Control Design by Dr. Jerome H. Ely.
Perception and Display Design by Dr. Jesse Orlansky.
Training Considerations Affecting Design by Dr. Jesse Orlansky.
Human Decision Making by Dr. Martin A. Tolcott.
Experimental Methods for Design and Evaluation by Dr. Martin A. Tolcott.

These seminars were presented to the Chemical Corps in March and April of 1960.

Because of our previous experience we not only invited section level personnel but also representatives of middle management from the various commands and the Chemical Corps Board at Edgewood to attend the circuit seminars. A follow-up questionnaire was again administered (as far as we know, none of the other technical commands followed up in this way). This questionnaire is attached as Table 3. Again without going into the details of the responses received, we can summarize the answers by saying that managerial personnel now seemed more convinced of the value of Human Factors Engineering and stated that they would make organizational assignments such that their colleagues would become more aware of this tool and use it accordingly.

The experiences described above may be useful to other divisions of the Army where human factors emphasis may be a marginal but relevant phase of the research, development, and production mission of that division.

TABLE 3

Follow-up Questionnaire to Participants in Circuit Seminars

1. Please try to recall items of equipment which have been developed over the past year or two. If you had attended this seminar two years ago, could any of these items have been improved? Please list such items.
2. In a program such as this, what information should receive:
   a. More emphasis?
   b. Less emphasis?
3. Please suggest other types of information which you feel would have been helpful to you and others in this seminar.
4. Do you intend to inquire further into the usefulness of human factors engineering in your own area of work?
   a. If so, how?
   b. If not, why not?
5. Should this program be extended to others:
   a. If so, who should attend?
   b. How often should it be given?
6. a. Would a 3 month university course in human factors engineering be beneficial for:
   Engineers
   Managers
   b. Would you support sending one of your men to such a course?
   Yes
   No
7. Please check below those human factors engineering services which you feel would be of value:
   Human factors information for use in specifications.
   Special human factors engineering handbook for the Chemical Corps.
   Special human factors engniee ring check lists for the Chemical Corps.
   A human factors engineering laboratory at the development labs.
   A human factors engineering consulting group.
   Advanced training in human factors engineering for:
   Engineers
   Managers
   Presentation of human factors engineering case studies (local seminars).
   Human factors engineering workshop (problems vs techniques for solution).
   Procedures for human factors engineering review of designs.
8. (This question asked for the organization and the level within the organization from which the participant came).
9. Remarks:

B. PSYCHOPHARMACOLOGY AND HUMAN FACTORS ENGINEERING IN THE U. S. ARMY CHEMICAL CORPS, by Dr. Earl Davy, Chief Psychology and Human Engineering Branch U. S. Army Chemical Center, Md.

[Unclassified Abstract of a CONFIDENTIAL Paper]

The Mission of the Chemical Corps Psychology & Human Factors Engineering Branch includes two general objectives. The first of these is to determine the effects of drugs upon man in terms of the extent to which they increase or decrease the proficiency of his performance as measured by tests of specific sensory, motor, and ideational

capacities and by his ability to execute representative, standardized, military tasks. Related objectives include the determination of accompanying changes in motivation, affect, decision making capacity and physiological state. The second general objective is to conduct human factors research related to the design and use of Chemical Corps equipment.

The specific activity areas of the Psychology & Human Factors Engineering Branch are as follows: The first of these is the use of Laboratory Tests to measure the effects of chemical agents in human subjects. The second is the determination of the effects of these agents upon personnel engaged on military type tasks. In our new operant laboratory we are using highly specialized techniques to study the behavior of lower animals. The fourth area is that of Human Factors or Systems engineering which concerns the relationship of an operator to the equipment he uses.

In measuring human behavior in the laboratory and in the field, characteristically each test or task, in its identical or in a comparable form, is repeated by subjects in both a drugged and a normal condition. The order of presentation of test conditions, i.e., drugged or normal, is counterbalanced to rule out the effects of practice upon performance. Whenever possible each subject is used as his own control.

During the past year an operant laboratory has been set up. The experiment in this laboratory is of a sort which will permit the experimenter to control the environmental consequences of a simple and immediately repeatable motor act. He is also able to control a variety of stimuli which may impinge upon a subject organism during an experimental session. Both these stimuli and the environmental modifications which follow the execution of a motor act may be pre-programmed and generated by the use of specialized automatic equipment. The critical responses of the organism are electro-mechanically recorded.

A major objective included in the mission of our branch is the continual review of all items of Chemical Corps equipment during the period that these items are being conceived, designed, and developed. This review concerns the design and recommended method of operation of this equipment from the viewpoint of human use. Our initial or laboratory tests of Chemical Corps equipment from this viewpoint typically involve preparation for operation or actual use according to a set of instructions. After the laboratory tests have been completed, and after a sufficient number of duplicates of the item have been made available, a second series of tests may be carried out under field conditions. The field conditions include temperature extremes, or in the instance of field tests of protective clothing, the performance of military tasks while the item is being worn. If the equipment is complex, field trials may include evaluation of ease of maintenance.

CHAPTER 8

U. S. ARMY TRANSPORTATION CORPS PRESENTATION

AVIATION CRASH INJURY RESEARCH by Francis P. McCourt, Chief Research and Analysis Division, U.S. Army Transportation Research Command, Ft. Eustis, Virginia

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The major objective of aviation crash injury research is to provide data for engineering design which will, in turn, assure survival - with little or no injury - in aircraft accidents which involve survivable conditions of crash force.

Many will agree that so long as a human being is in any way associated with the design, construction, maintenance, and operation of air vehicles - - - - "There shall be accidents!"

It does not necessarily hold true, however, that so long as we have aircraft accidents - - - - - "There shall be injuries and deaths!"

Experience has shown that, under certain conditions, human structure can withstand exposure to impact forces which will normally disintegrate aircraft structure. Considering then, the capability of the human body to with stand certain magnitudes and direction of force application, it becomes possible to proceed to isolate and classify predominant injury producing factors which may be revealed through the crash-injury study of aircraft accidents. Such investigations and analyses clearly indicate that force, in itself, has not been the outstanding cause of injury or death in aircraft accidents.

In order to provide data useful for the development of crash safety engineering specifications, requirements, and design, a number of "tools" are necessary as well as "know-how." These involve the development of methodology, experience, and the ability to define the type of information needed, to obtain and classify the information in an orderly and useful manner, and to analyze it and reduce it to usable data. Then the data must be analyzed and interpreted; the interpretation, in turn, must be reduced to usable and practical data for the engineer.

Some aircraft accidents are classified as "extreme" due to complete disintegration of structure, extreme impact forces, or post-crash fire. Occupants involved in these accidents usually sustain fatal injuries. Accidents such as low speed ground-loops or nose-overs, which are merely "incidents," on the other hand, involve little or no exposure to injury.

At this stage of the game, and for some time to come, it appears, it will not be practical to do more than think about ways to design for survival in the case where an aircraft flies straight into the side of a mountain at 400 miles an hour. And since the injury factor in "incidents" is insignificant, the accidents occurring between these two extremes are those which provide valuable data on crash-injury problems.

Useful crash survival data, therefore, is produced through the study of accidents in which the conditions are classified as "moderate," "moderately severe," "severe," and "extremely severe." These are the accidents in which there is a definite exposure to injury (whether injury occurs or not) and in which the total energy of the crash is insufficient to completely collapse the occupiable (cabin or cockpit) structure.

Let us consider an airplane accident in which the crash force imposed on the aircraft is within the known limits of human tolerance. Excluding crash fire, drowning, etc., (which is another problem entirely) injuries sustained are generally produced through any of these five methods:

(a) By having structure collapse sufficiently to impinge upon (or crush-in) vital body areas;

(b) By becoming a far-flung missile (Example: The seat in which you are restrained may fail at its floor attachments, allowing you to be thrown against forward structure or even out of the aircraft);

(c) By becoming a near-flung missile (Example: Your seat and safety belt remain intact but your head, upper torso, arms and legs are allowed to flail forward or to the side, striking adjacent structure);

(d) By being struck by a missile (Example: Fire or oxygen bottle, another occupant, loose equipment stored in the area, which may fly forward to strike occupants.

(e) By magnification of the crash force itself (Example: Bottoming against a rigid, non-yielding piece of structure).

After isolating any one or more of these basic injury-causing factors - in any given accident - it becomes apparent that the "fix", or corrective modification, for any of these conditions is largely a matter of engineering design.

First of all, let us consider the structure which, under force application, allows itself to be crushed in against an occupant. The logical fix in this case is to provide a structure which is more "crashworthy." Once we have provided an environment or container which, under reasonable application of force, will not crush inward, we have the basic structure needed to correct the other four injury-producing conditions.

The fix required to prevent an aircraft occupant from becoming a far-flung missile involves an adequate "tie-down chain." The occupant must be securely restrained in his seat, the seat must be adequately tied down to its track, the track must be securely fastened to the floor, the floor must be securely attached to basic structure, etc. Design strength requirements indicated along these lines may well be in the order of 50 to 60 G in order to be fully effective in some survivable crashes.

The fix required to correct the condition known as "becoming a near-flung missile" involves either (a) adequate protection for the body areas which may strike surrounding structure (this may be accomplished through the use of a crash helmet and/or shoulder harness) and (b) "delethalization" of the environment within striking range of the body (this may be accomplished by padding with high energy absorbing material, recessing instruments and knobs, providing breakway features in instrument panels, control sticks, etc.).

Of course, there should be no excuse whatsoever for ever being struck by a missile during a crash impact. Fire bottles, oxygen bottles, galley equipment, tool boxes, batteries, radio gear and the like should all be securely attached in such a manner that they will stay in place, even under high impact loading.

Finally, the fix involved to prevent injury through transmission or magnification of force may be simply stated in three words, "provide energy absorption." As an example, this might include utilization of seat structure which yields and deforms progressively under crash loads - absorbing energy.

All of these various facets provide some insight as to what the crash-injury investigator should look for during his investigation. His prime concern is to find specific injury -- or death -- producing factors. It must be noted here that it is of equal importance to determine and report on any evidence of "planned" or "inadvertent" design features which contributed to survival and the modification or prevention of injury.

Another equally important phase of aviation crash injury research involves obtaining precise crash load data from experimental crashes. Such data, when integrated with information from analysis of actual accidents, will provide precise engineering data for use in developing design specification. This phase of research involves actual crash testing of surplus or phased-out (and perhaps prototype) aircraft of typical design. This testing utilizes relatively low-cost track-type test facilities on which air vehicles (fully instrumented with anthropomorphic dummies) can be crashed at the velocities and impact angles typical of their low speed operating range. Data derived from tests of this nature will permit precise engineering design for crash-safety without the weight penalties which result from static, rather than dynamic, testing. The first such test sponsored by the army will actually take place within the next few days, somewhere around the 17th, at the Aviation Crash Injury Research Division of the Flight Safety Foundation in Phoenix, Arizona.

This test involves the use of a truck mounted crane to which will be attached an H-25 helicopter. The truck will drive along at a speed of 35 miles per hour with the helicopter suspended some 50 feet in the air. When the desired conditions are reached, the H-25 will be electrically released from its hook by means of a control located in a fully instrumented TC shop van. At the time of release all instruments and cameras will begin operation to record data through the crash sequence. A full scale practice drop, utilizing telephone poles arranged in a configuration simulating, as nearly as possible, the exact shape and weight of the H-25, was conducted in September and the results were perfect. So, the procedure appears sound and we contemplate no difficulties during the actual test.

We recognize, of course, that such improvised test facilities lend themselves to unforeseen problem areas. What is really needed is a dynamic testing facility which will allow for the dynamic testing of seats, floor structure, equipment installations, portions of aircraft structure, etc., in order to determine their behavior in survivable-type conditions. Investigation indicates that there is no existing facility which will meet these requirements. Thought is being given to conducting a study to determine the feasibility of constructing such a facility from the standpoint of engineering problems and costs.

The work conducted to date in the field of aviation crash injury research has been very rewarding. As a result of investigation of army aircraft accidents by AVCIR, several design deficiencies have been noted and are being corrected. I feel sure that the recommendations contained in the report of this H-21 accident relative to seat structure and tie-down-chain deficiencies will be acted upon in future specifications.

This sequence of slides depicts an HU-1A accident and structural inadequacies are obvious. I am happy to state that as a result of our crash injury research program HU-1B aircraft will have many improvements. For example, the door posts weakness will be corrected by addition of a roll-over structure to the pilot and copilot seats. This will provide a structure capable of withstanding a vertical load of 3500 pounds per seat, an increase of 100 percent, for the infinitesimal weight increase of 3.5 pounds. Other improved features such as anchoring seat belts and shoulder harnesses to the floor structure will be incorporated.

I believe it has been conclusively proven that crash-injury investigation, analysis, and reporting are a necessary - and permanent - part of aviation safety; likewise, the development of crash safety design requirements through the channels of military specifications, model specifications, and design handbooks are a continuing necessity. Evaluation of mock-ups and of current types of aircraft with subsequent analyses and reports, also will aid in pointing out crash safety design

deficiencies existing in current aircraft and current design thinking.

Since air vehicle design is constantly changing as new performance requirements are developed, the investigation and analysis of accidents from a crash-injury point of view and the laboratory (dynamic) testing of such vehicles should be on a long-range basis just as accident investigation and the testing of components for the prevention of accidents is on a continuing basis. This means that air safety must involve continuing attention in two areas (1) accident prevention, and (2) injury prevention.

CHAPTER 9

ARMY-WIDE HUMAN FACTORS R&D PRESENTATIONS

A. SOME RELATIONS BETWEEN TRAINING RESEARCH AND HUMAN ENGINEERING IN THE DESIGN OF WEAPON SYSTEMS: Dr. Theodore R. Vallance; The George Washington University, Human Resources Research Office, Washington, D. C.

B. HUMAN FACTOR STUDIES IN TACTICAL PHOTO INTERPRETATIONS: Dr. Joseph Zeidner, Personnel Research Branch, The Adjutant General's Office, Washington, D. C.

C. THE ACCURACY AND COMPLETENESS OF INDIVIDUAL AND TEAM PHOTO INFORMATION EXTRACTION: Dr. Robert Sadacca; Personnel Research Branch, The Adjutant General's Office, Washington, D. C.

D. U.S. ARMY PARTICIPATION AT THE U.S. NAVAL TRAINING DEVICE CENTER: Dr. Kenneth F. Thompson; U.S. Naval Training Device Center, Port Washington, Long Island, N.Y.

A. SOME RELATIONS BETWEEN TRAINING RESEARCH AND HUMAN ENGINEERING IN THE DESIGN OF WEAPON SYSTEMS by Dr. Theodore R. Vallance, the George Washington University Human Resources Research Office

This is the first occasion of a HumRRO inside presentation before the Annual Human Factors Engineering Conference. I say "inside presentation" because our previous participation has been as an interested observer and guest. Now we are told that there is a good likelihood that we can look forward to closer ties between HumRRO and the Army's community of human factors engineers. The nature of these ties remains to be clarified by experience and demands.

It is my privilege to make a start toward developing the function and position of HumRRO in the Army's HFE community by addressing the conference today. In so doing I should like to do two things. First, I should like to give a short orientation talk about HumRRO, its organization, deployment, and method of operation. I hope that these remarks will not be too redundant within this audience, though if they are, I shall be happy that so many already know so much about HumRRO. The second thing I should like to do is to discuss some relationships between those activities called training research and those called human factors engineering. In the course of this I shall mention a few of our activities that have some logical or, as is occasionally the case, accidental, relationship to activities commonly associated with the term "human factors engineering." Out of these two sets of ideas, plus those coming from the Personnel Research Branch for The Adjutant General's Office with its new and closer ties with the AHFEC, we hope that over the next few years a more integrated and even more effective total human factors research and development program for the Army may grow.

Now for the review of HumRRO. The Human Resources Research Office is the Army's vehicle for conducting "such studies and research in the fields of training, motivation, leadership, and man-weapons system analysis as are mutually agreed by the Department of the Army and HumRRO," according to AR 70-8. We are in our tenth year of operation. HumRRO has several existences. It is an office of The George Washington University whose name appears on our salary checks and purchase orders. It is a creature of the Office of the Chief of R&D, as indicated in the AR just cited. HumRRO is also, in part at least, a branch of Headquarters, Continental Army Command (CONARC).

The organization chart in Figure 1 portrays these existences. The line from the Department of the Army to The George Washington University shows the contractual relationship and fiscal life line of HumRRO. The line between the Director's Office and the Office of the Chief of R&D portrays the flow of authority and responsibility. Most of HumRRO's business at DA level is conducted with or through the Human Factors Research Division.

The relationship with CONARC must look odd to those interested in organizational theory. CONARC, being responsible for training the Army in the United States, is the major consumer of HumRRO research. It is also the support of HumRRO research. CONARC support comes by way of making needed troops and material available for training experiments, and by way of providing guidance for and direct participation in the research through the Human Research Units which are located variously around CONUS. The odd looking feature is the existence of two lines of authority to the five field laboratories, the Human Research Units--one line from the Director of HumRRO to the Unit's Director of Research, and one from CG, CARC, to the Unit's Military Chief. Both bosses of the Units have the same mission but get their orders (and efficiency reports) from different headquarters. Of necessity then, there is a great deal of traffic over the coordination line between HumRRO and CONARC. Considering this obvious violation of accepted organizational structure, together with the complexities of developing an annual Work Program, it is apparent that HumRRO is a wondrously complex organization. It is a tribute to the good will, patience, and devotion to the Army on the part of all who are entwined in this system that it works as well as it does--and we think it works pretty well.

To complete the organizational story, I must say something about the Training Methods Division, which is located in our main building on the GW campus. TMD does not have a military contingent (except for occasional specialists on extended temporary duty), and is not as responsible to CONARC as are the HRU's. TMD's program of research typically grows out of training problems expressed (or concurred in) not only by CONARC, but by a number of other Army agencies or commands--most prominently the Technical Services, such as the Ordnance, Signal, Transportation, and Chemical Corps.

So much for organizational matters. Now for a short review of the research program. You will not be surprised when I say that content of the R&D in the HRU's is noticeably influenced by the military activities that predominate at the five posts where the HRU's are located. At the Armor HRU, ties with the Armor Board, the Armor School, and the USA Training Center (Armor), are close. The HRU gets much logistical support for its entire program in return, one

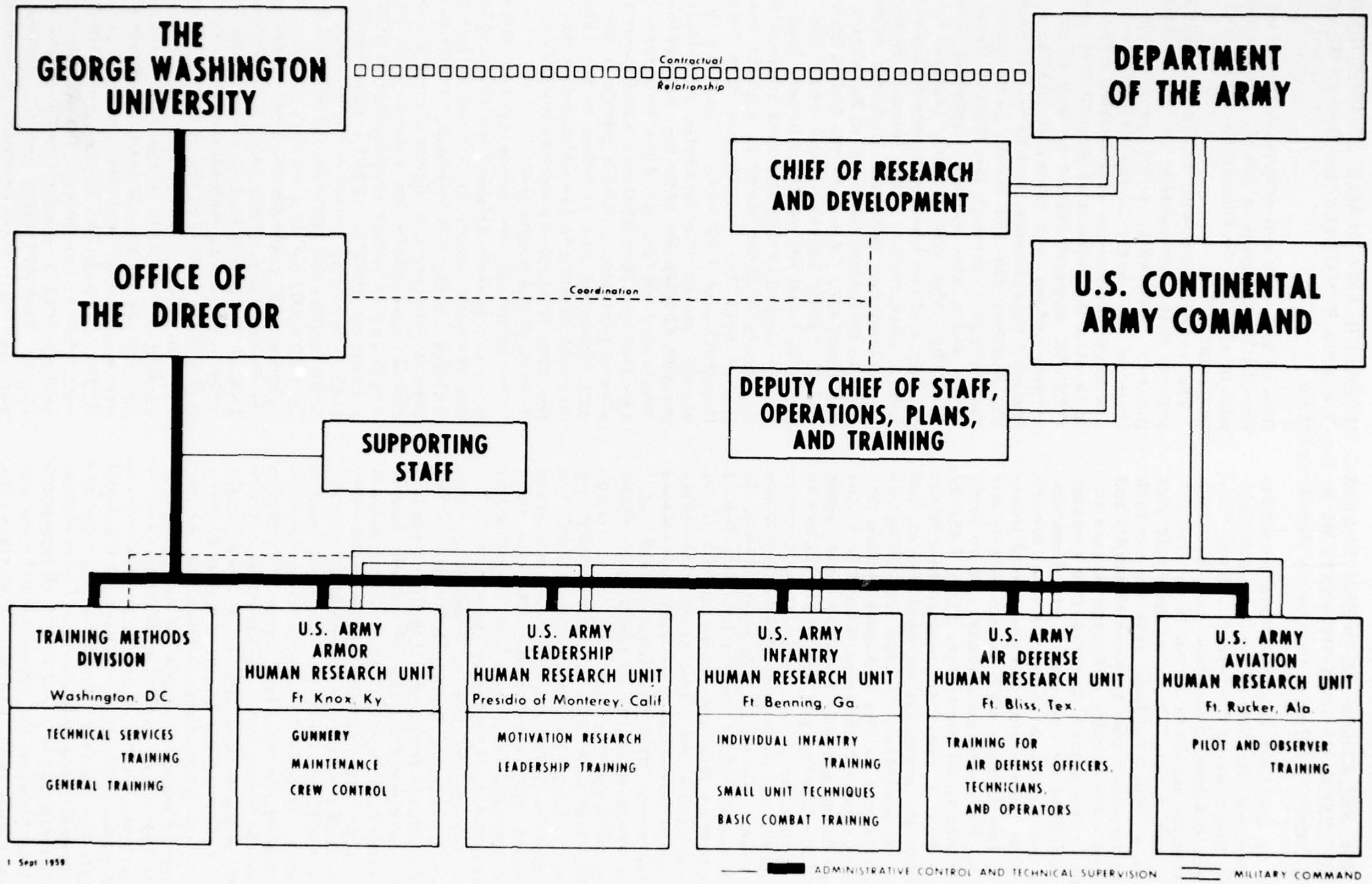

Figure 1. Organization Chart for Human Resources Research Office.

might say, for development projects related to current or imminently impending problems in Armored firepower, vehicle maintenance, and unit training, as well as for some longer range research in command and control and night combat. Parallel statements can be made about the other three HRU's (Infantry, Air Defense, and Aviation) that are located at the major centers.

Our Infantry HRU has among its projects a study of junior officer leadership, one of infantry combat skills under low illumination levels, a development effort on practically the entire job of the light weapons infantryman, and an effort to apply techniques of automated teaching to basic combat training.

At Fort Bliss, the Air Defense HRU is studying skills of supervision and management for Nike battery officers, programmed self-teaching methods for electronic repair jobs, Nike fire control operator skills, and developing a method for expeditiously getting all kinds of training-relevant information from various stages of weapon system development into the hands of training agencies. Also, a new method of electronic trouble shooting at the system level is now under test.

HumRRO efforts in the Aviation field are concerned with developing and testing an improved method of simultaneously teaching instrument and ground-contact orientation skills to fixed wing pilots. An extensive study of aerial observer duties and training procedures is nearing a close, and a research program on training helicopter pilots is well off the ground.

At Fort Ord, where lives our Leadership HRU, we are at work on some problems of Army-wide interest, NCO training, career motivation, performance under stress.

From what I have said you can infer that the scientists at the HRU's have a rather active relationship with the various Army agencies at their posts. This relationship constitutes a source of research and development problems and ideas, and is a good vehicle for getting research results put to work. It also results in our units being called upon for advice and services which aren't strictly a part of HumRRO's official mission. For example, we have advised on grading and scaling procedures at the Armor School, assisted the Aviation Board in designing a human engineering appraisal of the H-37 helicopter, produced a short self-taught course in methematics for the Air Defense School, aided the Infantry Board in evaluating some new rifle sights, assisted the Armor Board in its evaluation of the T-95 tank prototype, and have run a short course on how to evaluate tactical concepts in a two-division maneuver. These extracurricular activities are informally squeezed into the cracks of the regular Work Program (and sometimes the cracks are widened a bit to accommodate them). It is difficult to say "no" to requests for consultative services--particularly when the Director of Research knows that next week he might ask the Board for $5,000 worth of ammunition, or to use two tanks for several days. And besides, it's usually fun. Right now the Aviation HRU is running, with the Aviation Board, a feasibility test of a manned, low flying, high speed aircraft for use in battlefield surveillance. We hope the name for this project remains inappropriate: it is called Project SMASH.

Living and working closely with the schools and boards have necessarily caused us to see more clearly some of the relationships between our primary mission of training research and other peoples' missions in the human engineering field. So let me now move to my second topic in this, suggested in the title: relationships between training R&D and human engineering in system design.

Time does not allow a thorough exploration of this topic, nor a proper treatment of the important relationships which selection and classification research has with both training research and human engineering.

As an opening thought I must state the platitude that whatever any of us human factors researchers is doing has, either by design or sheer accident, <u>some</u> bearing on maximizing the efficiency of some system. As an article of faith we in applied research accept the notion that the more extensively we can specify the structure and function of relevant systems, and the more clearly we can perceive the bearing of our applied research on those systems, the more likely we are to produce some means of designing a man-equipment system that will achieve the desired ends with acceptable costs. This article of faith pertains much more closely to development than to applied research, and not at all to basic research. I state the platitude in order to provide a framework within which to seek some relationships among the several research activities in which all of us are engaged.

I propose to develop the following points for your consideration. <u>First</u>, the distinction of training research from human engineering is fundamentally a matter of degree and emphasis.

<u>Second</u>, the distinction within the Army between human engineering and training research is in good part administrative and grows out of the organization of the Army.

<u>Third</u>, the process of weapon system engineering should consider the cost of the training subsystem along with other costs, as well as give attention to the proper linkage of man and machine.

<u>Fourth</u>, last, and most obvious, improved coordination in planning and conducting human factors research and development, both within the human factors family and with the developers of Army hardware, will go a long

way toward developing better system design models and eventually better systems.

Now regarding the first point--the difference of degree and emphasis between human engineering and training research. Let me develop this through a series of examples.

The HumRRO unit at Fort Knox was asked by CONARC to do something toward improving training for tank combat at night, especially when searchlights could be used. We early learned that next to nothing was known about the effects of various kinds of searchlights on target detection and identification, or about the difficulties of vision that could be imposed on (or by) the enemy through various uses of lights. In other words, no one seemed to know what the training problem really was. Our first efforts, then, were to try to define the problem through some psychophysical field studies that would tell us something of detection and recognition thresholds, expressed in terms of distance from target, that would hold for various deployments of lights and target vehicles. We have learned some fairly basic things about detection and recognition thresholds, and these have been written into the appropriate training circular. We are now in a pretty good position to see if we can't devise training methods to change the thresholds or reduce the time required for recognition and detection. Thus, a system engineering study--in the form of analysis rather than design--preceded training research.

We have another example at Fort Knox in which a human engineering-like study is paving the way for some relatively pure training research. We call this Task SPANOCON because it deals with span of control. The problem is related to efficient use of officer manpower and the Task seeks eventually to devise ways of training officers to control a maximum number of subordinate elements without too great a risk of bad decisions or personal breakdown. Again, our efforts have been directed toward clarifying the training research problem, and we have been running a series of simulation tests in which we have varied systematically the number of tanks in a platoon and required variously experienced officers to command these platoons in offensive and defensive tactics. Through these exercises we have learned much about the details of small unit command activities that have not been previously quantified, and have identified some which appear to be trainable, and some which are not. We find ourselves only now ready to undertake training research directly--i.e., to examine the conditions of practice which are associated with variations in ability to receive, interpret, evaluate, and act upon combat-relevant information.

You will be interested, I believe, in one more example of a system study preparatory to training research--this time one which led to the decision that training research was not warranted. Question had arisen about the accuracy with which tank gunners could lay the cross hairs of the sight on a target and of the possibility of increasing hit probability through better training in this part of the lay-fire cycle. Our Fort Knox Unit succeeded in instrumenting a tank and a firing range such that it was possible to measure within a small fraction of a mil the true point of aim at the time of triggering. The researcher also measured the deviation, from that point of aim, of rounds actually fired. The purpose, of course, was to separate the human and the machine components of fire dispersion so that we could know how much system gain could be expected from improved performance by the gunner. To our surprise we found that the gunner part of the dispersion was only a relatively small fraction of the hardware part; and moreover, this held true for relatively inexperienced gunners as well as for the old hands. Apparently the human engineering of this system was so well done that learning as accurate a performance as the hardware allowed was made extremely easy. This is as good a demonstration as I know of the truth of Frank Taylor's assertion that if equipment is perfectly human engineered, the training problem is zero. Naturally, we turned our gunnery training research efforts in other directions and our findings over to the Ordnance Corps.

The common element among the examples I have given is that a system analysis effort preceded experimentation on improved learning conditions. I cannot support a claim that these analyses were exhaustive; but they rendered much more explicit the role of human performance in these man-machine systems.

What, then, are the features relating human factors engineering research to training research? The best simple portrayal I can find looks about like Figure 2.

It appears to me that human engineering, as most commonly practiced, tends more than training research to be concerned with linkages of man and equipment, to be more analytical and variance oriented, and to work in systems whose components are fairly explicit and relatively stable (i.e., contain much hardware). Studies of conditions affecting sensory discrimination, information analysis, direct feedback processes, response accuracy and constancy--most of them dealing with close connections of machine with man--abound in the human engineering literature. Human engineering parameter finding studies, such as those of Hicks and Cohen which we heard reported in the last two days, are important works fundamental to trying to improve total performance, once the sources of variance are identified. In many instances training research may be an

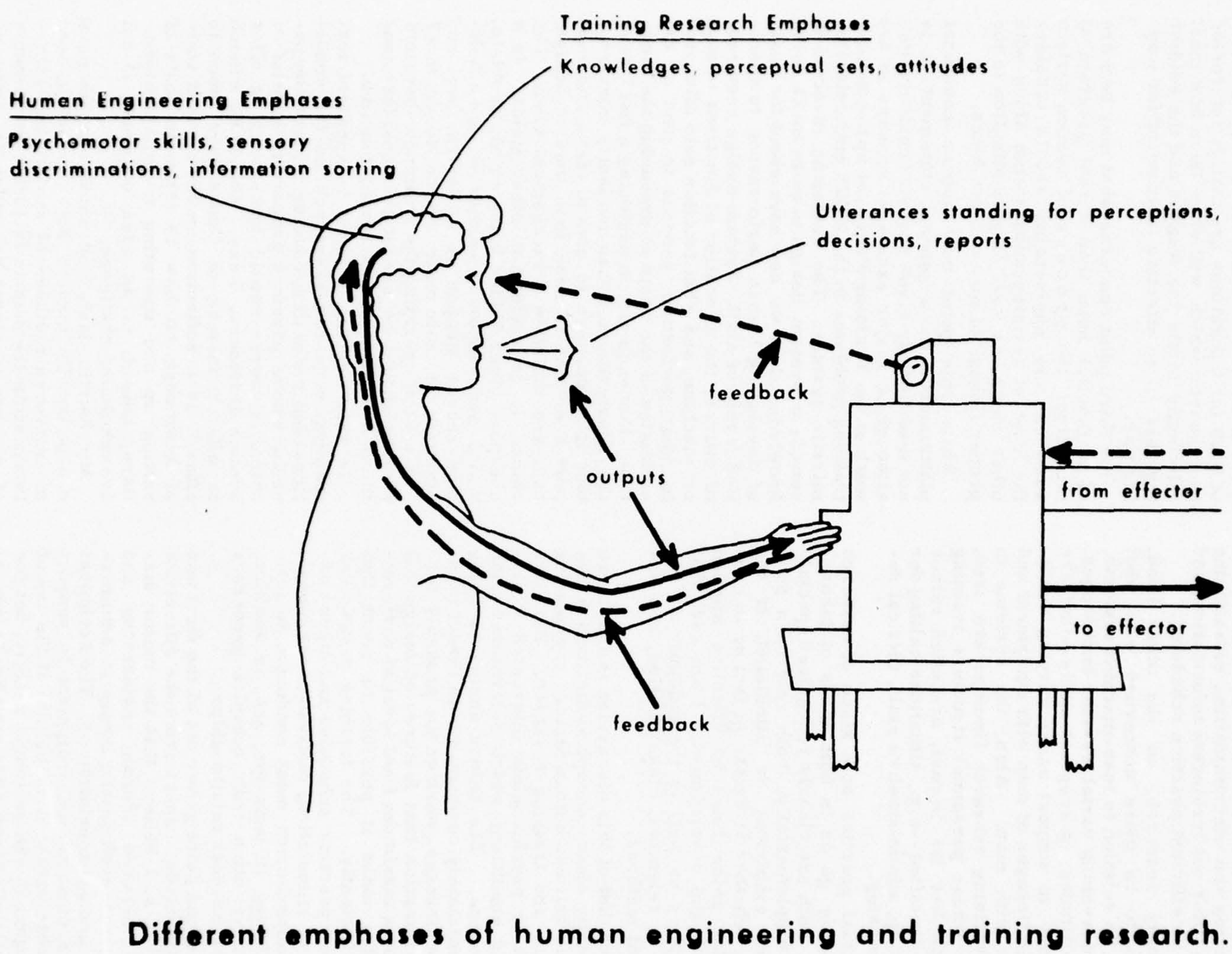

Figure 2. Different emphases of human engineering and training research.

Avenue to improved human output. The studies reported by Captain Hawkes are especially interesting in this connection--if discrimination via tactile modality can be made fine enough to pass a useful range of information, then some training research can be directed toward discovering ways of maximizing the discrimination, establishing sets to filter out irrelevant information, and setting up efficient practice schedules.

Training research, on the other hand, appears to be more concerned with what appear, in relation to man-machine systems, to be intervening variables--the knowledges, sets, attitudes, perceptual skills--that are necessary to support under varying conditions the linkages of man with equipment and of man with man. Also, the systems in which training research findings are used, and on whose personnel structure training research has its impact, are often rather poorly specified--e.g., situations calling for leadership, administrative skill, tactical decision making.

In actual practice both kinds of research necessarily go on in both kinds of laboratories. Both are clearly recognized specialties. Fundamentally, both rely on a good analysis, empirical or simulated, of the system, whether it exists in fact or in concept, for guide lines to effective applied research and development. I am sure that this applies as well to the guidance of research in selection, classification, and assignment methods.

One upshot of this discussion is that there is no really clean conceptual distinction that I can see between human factors engineering research and training research. Both are pursued by psychologists interested in discovering conditions which determine human performance. The human engineers being more intimately concerned with direct man-machine linkages, work on the probably correct assumption that features of design that make for a maximum final level of performance also make it possible to reach that level efficiently. The training researcher looks for practice schedules and other conditions of stimulation, motivation, response, and reinforcement most conducive to efficient change in behavior, and, in addition, deals more often with complex processes and interpersonal relationships.

My second point grows out of the first and is briefly made: apart from the difference in emphasis, I believe that the major distinction between human engineering and training research in the Army is administrative, and appropriately so. The Technical Services must design equipment to support the combat arms; it is helpful if the use of the equipment can be taught readily, but for the details of operator training the Technical Services have relatively little responsibility. Hence the concentration of human engineering in the Technical Services.

The users of weapons have most of the training responsibilities, and so far only a modest impact on the configuration of the hardware in a weapon system. Therefore, CONARC and the Office of the Deputy Chief of Staff for Operations are mainly interested in research which will show them how most efficiently to tie the weapon and the soldier together in an effective instrument for waging war.

My third point concerns what may be more of a fanciful hope than a real program at this time: the process of weapon system analysis and engineering should consider the cost of training subsystems along with other costs, as well as give attention to the proper linkage of man and machines.

While this point may appear somewhat platitudinous as a general statement, it is not traditionally given serious consideration, although a major exception appears in the work of the Training Panel set up to consider training problems in the ZEUS anti-missile-missile system. The decisions involved in complete system design require much more knowledge than we now have about the costs of developing human performance to specified levels of skill. System design requires, of course, the allocation of functions to man or machine, and what function gets allocated to what performer depends in part on the estimates of the costs of producing the function. For example, in designing a field mess the quartermaster has evidently concluded that it is cheaper to obtain, train, and support a soldier to cook food than to design, buy, and maintain a mechanical chef. The choice is less clear in other fields. Is it cheaper, other things being equal, to obtain, train, and support a soldier to aim a helicopterborne weapon or to design, buy, and maintain an automatic device to do this? The cost of operating the training subsystem clearly should be one of the considerations in the allocation of this aiming function.

In this context, then, it is apparent that training research--research on the conditions and costs of producing system components whose physical properties consist of human tissues--should have much to offer system designers. I say, "should have much to offer," instead of "does have much to offer," as a reflection on our current state of knowledge on how to estimate costs of setting up and operating a skill factory. Here, indeed, is an area of great, if not overwhelming challenge.

My fourth, last, and most obvious point can be briefly made: We are much in need of improved methods of system analysis--forecasting the human factors requirements of weapon systems in order to optimize around desired system outputs with minimum

costs in training, hardware design, and manpower costs to other systems for which the same management (namely the Army) is responsible.

I shall use one final example. You will recall my account of the span of control study. You can see that this little study is related to--and in some ways includes--the decision making process, particularly with reference to the amount and classes of information that can be efficiently handled by the small unit commander. There is another variation on this problem not far in the Army's future. The Automatic Data Processing Systems may well upset a number of standard practices of command and staff and will surely pose some tough problems. The advances in solid state physics augur well for the possibility of building computers, that can handle vast amounts of information, so compactly that they can be hauled about in half ton trucks. I learned at Fort Huachuca the other week that ADPS technology may be able to make computers available at battle group level not long after 1965. Conceivably similar computers could be made available at company level in about ten years.

I believe it is safe to infer from past experience with military hardware development that if these computers can be made available, they will be made available. Therefore, I think it is not too soon to begin research that will, to some extent, guide the design of computers around the capability of small unit commanders to use information. In this problem are also important implications for research on selection and assignment for both officer and enlisted personnel. It is of little use--possibly it is even dangerous--to design computers and associated communication nets that will overwhelm the already harassed commanding officer and his staff with more information than they can efficiently use.

Wouldn't it be fine, we often muse, if full system studies could be completed by the time weapons and equipment are issued to troops? We should then know reasonably well the qualitative manpower requirements and what the training programs should look like, for the research and development on selection and training could have been well nigh completed before final production and issue of hardware. As things now stand, much of training R&D consists in retrofitting the training support of a weapon system. And like all retrofits, training retrofits are useful and necessary, but costly and awkward to introduce into the system. Obviously we are in need of more advanced guidance for our training R&D so that the design of training systems can be made more timely, better suited to weapon system needs, and less demanding of retrofitting. Close ties among the various parts of the Army's human factors R&D program will be of major value in guiding the research aspects of the program so that eventually the development work can go on in congruity with hardware development, and retrofitting of all kinds can go into a decline.

In summary, I am glad to have had this opportunity to tell you something about HumRRO, its mission and organization, and to review for you some samples of HumRRO research that exemplify a basic relationship between training research and human factors engineering.

I have concluded that training research and human engineering are two clearly recognized areas of specialization, that "systems thinking" is necessary in both but tends to blur any fundamental conceptual distinction. An important practical distinction is administrative, and in the Army, grows out of the responsibility of the Technical Services for weapons development and of CONARC for troop training in arts of war. Training research faces a major challenge in the problem of how to estimate the costs of skill components of the system. More active coordination among Army R&D agencies and improved methods of system analysis may enable us to evolve a still more effective program of Army Human Factors Research and Development.

B. HUMAN FACTOR STUDIES IN TACTICAL PHOTO INTERPRETATION by Dr. Joseph Zeidner, Personnel Research Branch, The Adjutant General's Office, Department of the Army, Washington, D. C.

1. Psychological Approaches to Image Interpretation

a. Background

What contribution can the measurement psychologist make to image systems research? The first part of this paper describes the kinds of problems in image systems which are appropriate to the techniques and skills of the measurement psychologist. The second part of this paper presents findings of current pilot studies, which illustrate the applicability of psychological measurement techniques to imagery problems.

Existing knowledge of the basic phychological factors underlying image interpretation is limited. In order to determine the human factors requirements in image systems, the Personnel Research Branch of the Department of the Army conducted an extensive exploratory study to define image interpretation problems. These problems were to focus clearly on the Army's needs, and at the same time be subject to research attack. The formulation of PRB's research program in this area was a direct outgrowth of this analysis.

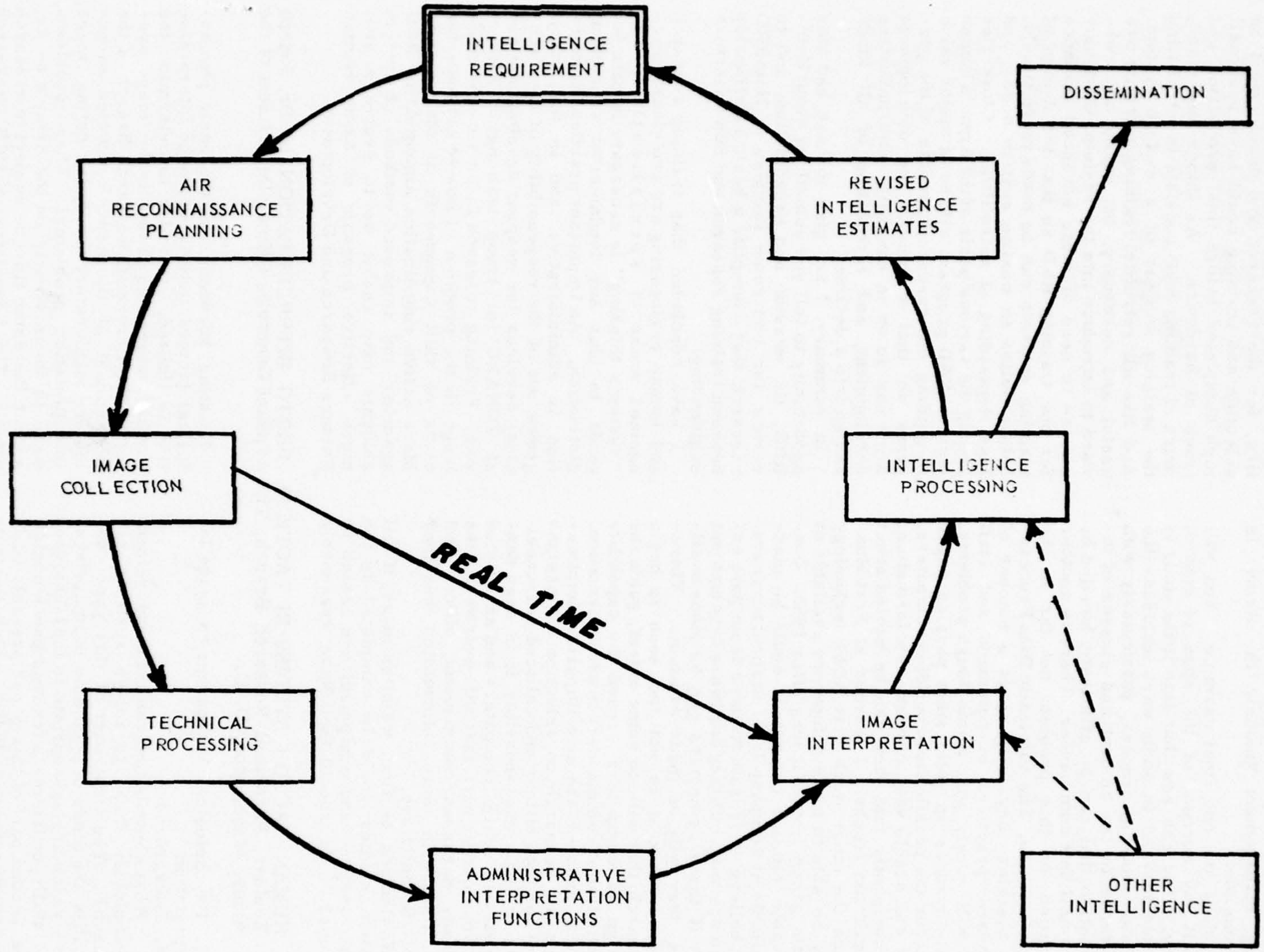

Figure 1. Aerial Surveillance Intelligence System.

The military requirement is for timely, relevant, complete and accurate intelligence information that can be derived from images and communicated to action people. The psychological requirement is an outgrowth of the rapidly advancing technological capacity of the military to procure imagery. This increased capacity has inevitably increased the range of image quality, some of which is quite poor. Until recently the photo interpreter was confronted only with the problem of interpreting large scale, high quality, conventional black-and-white photographs. Today, and increasingly in the future, he is required to interpret radar, infrared, fleeting, TV, small scale, and degraded images. The services have not only increased tremendously their capacity to process conventional imagery at a very rapid rate, but also their capacity to take aerial photographs from a variety of platforms, such as drones, balloons, and satellites. Technological innovation often diminishes the importance of human functioning. In the case of image systems, technology has increased the importance of human functioning. The core of image interpretation is the human doing the interpreting. With the advent of new imagery collection techniques, requiring rapid and accurate interpretation by fallible human beings, obtaining knowledge about the psychological factors underlying image interpretation has become an urgent requirement.

b. Image Interpretation as a Part of the Aerial Surveillance Intelligence System

The relationship between PRB image interpretation research, which is largely concerned with the image interpreter subsystem, and the entire aerial surveillance intelligence system is shown in Figure 1. The system cycle starts with the projection of the military requirements by the commanding officer and continues with the planning of the flight, the type of coverage specific to the commander's requirements; decisions as to the type of platforms and sensor to be employed; processing of the images into hard copy; storage, retrieval and annotation problems within the administrative phase; the image interpretation; the assimilation of information by the G2 Air Officers; and ends with the revised intelligence estimates. "Real time" refers to instant image television transmission, a comparatively recent development in intelligence gathering.

Each of the other subsystems affects the performance of the image interpreter. For his part, the image interpreter is indirectly involved in planning and decision-making in each of the other subsystems. For example, in determining the need for air reconnaissance to answer a military requirement, the image interpreter is in the best position to know the existence of a "holiday" or gap in coverage because he knows the limitations and capabilities of each type of sensor. He is therefore likely to have a strong influence in determining what kinds of sensors and what kinds of platforms will be employed. The Personnel Research Branch is at present directing its efforts to problems within the image interpreter subsystem. At a later date research may deal directly with the other subsystems within the overall surveillance-intelligence system.

c. Subtasks in Current and Project Research Program

The initial PRB study broached two problem area. The question framing the first areas is: What techniques and what corresponding skills and abilities are necessary for the extraction of information from image system products? The second question focuses on the psychological factors in PI performance in the special context of Army operations. Given an everincreasing variety of types of images, what quality of personnel is able to meet the Army's standards for speed, accuracy, and completeness of information? Other approaches have concentrated on determining how the quality of the photograph can be improved. The PRB approach assumes the fact of poor quality imagery, and aims for better and more intelligence information by means of: (1) selecting potentially better photointerpreters and (2) rationalizing their use of equipment; (3) improving the procedures and techniques they employ; and finally (4) the synergizing of group members interactions for improved image system functioning.

As a result of its exploratory study into the psychological factors implicated in image systems, PRB formulated a research program which was divided into five nuclear subtasks.

1. Identification of Basic Factors in Image Interpretation
2. Development of Selection Techniques for Image Interpreter Personnel
3. Utilization Measures under Conditions of Emergency Demands
4. Identification of Basic Factors in "Real Time" Interpretation
5. Effective Group Patterns for the Accomplishment of Major Image Interpreter Missions

d. Identification of Basic Factors in Image Interpretation

The current effort at the Personnel Research Branch is largely devoted to the first subtask: Identification of Basic Factors in Image Interpretation. This subtasks is divided into five projects. The <u>first</u> project is identifying the significant variables in the job of image interpretation as they relate to individual differences. What is the nature of interpreter skills? Is it uni-dimensional or factorially complex? Does the individual who does well in directed search do as well in free search?

The objective of the second project is the improving of image interpretation techniques. What does the proficient photo-interpreter do that the unskilled photo-interpreter does not do? At present, very little is known about maximum payoff proficiency behaviors. The second project will involve analyzing skilled versus unskilled PI behaviors.

The third project is concerned with determining what it is a man needs to know about a target as compared to what he needs to see within a given photograph. What are the minimum components and what is the residual pattern of components that make for proper identification? This project is particularly important for improving interpretation of degraded images.

The fourth project involves the codification and standardization of information extraction procedures, particularly those used for flash or immediate reporting. Much interpretation time can be saved if a standardized procedure can be developed to meet military requirements and objectives.

The fifth project will explore the interrelationships of speed, accuracy, and information completeness. For example, what effect does emphasis on speed of output have on volume and accuracy of the product? This study should provide formulations of workload parameters which can be used for subsystem model development.

e. Development of Selection Techniques for Image Interpreter Personnel

Our second subtask, "Development of Selection Techniques for Image Interpreter Personnel," has its objective the identification of efficient photointerpreter personnel before training and assignment. (This kind of study is, of course, the traditional work of the measurement psychologist. A point to be emphasized, however, is that the skills involved in such a study can be very useful in other aspects of imagery research.) An experimental battery of tests is now being constructed. The battery includes aptitude tests, tests of interest and motivation, and personality tests. The best of these predictors, selected by tryouts in the PI school and on the job, will be made operational. It is obvious that a more efficient selection technique should result in intelligence information of superior quality.

f. Utilization Measures under Conditions of Emergency Demands

"Utilization Measures under Conditions of Emergency Demands," our third subtask, prefigures the stress and strain of the combat situation. What type and amount of stress produces critical deterioration of information? How can the effects of stress and fatigue be most effectively counteracted, thus enabling the photointerpreter to continue producing useful information? Projects designed to answer these questions have been established. The objective of one project is to ascertain what speed imperatives can be imposed on the photointerpreter without deterioration of product. Another project will investigate the effects of long uninterrupted work effort. A third project is concerned with discovering what product changes will result with changes in the set or work attitude of the photointerpreter. The photointerpreter is trained to be extremely cautious about the information he provides. Because of this psychological set he may be reluctant to make identifications when given degraded images to interpret. This study will probe the limits of interpreter accuracy under conditions of special demand and image degradation.

g. Identification of Basic Factors in 'Real Time' Interpretation

"Real time" interpretation refers to interpretation of television screen images transmitted by aircraft, either manned or drone. All the problems of hard copy image interpretation are also pertinent to "real time" interpretation. But many new problems requiring investigation have sprung up from the development of this new reconnaissance medium. The essential inquiry is: What are the psychological limits within which maximum utilization can be made of this "instant" intelligence-gathering equipment?

h. Effective Group Patterns for the Accomplishment of Major Image Interpreter Missions

The fifth research subtask, "Effective Group Patterns for the Accomplishment of Major Interpreter Mission," focuses on the photo interpretation group. The first project will study typical wartime photo interpreter missions and will develop standards of effective accomplishment. The second project will attempt to find new improved procedures for mission accomplishment. These studies will provide information on optimum size of unit and on the skill levels required for mission accomplishment. The result should be a Standing Operating Procedures manual for mission accomplishment, procedures which are compatible with psychological knowledge of group functioning.

2. Findings of Research in Progress

a. Direction of Current Effort

To answer the key research questions just described, a critically necessary first effort was the development and tryout of a series of performance measures, typical of real-life situations which confront the photointerpreter. The performance measures, once developed, would serve as the criteria or indexes of interpreter system's output for all of our research efforts. A great deal of developmental work went into the construction of these measures, in terms of selecting appropriate content or photo target materials, obtaining adequate photo quality

ranges, interpreting thousands of photos, developing both the keys and the concepts underlying the scoring rationale, posing questions and tasks for examinees, and writing realistic scenarios for the measures. Only by using photographs from actual tactical and strategic air reconnaissance missions could we most efficiently uncover the relevant psychological dimensions of Army photo interpretation. As in the operational situation, the performance situation includes the use of maps, sortie plot overlays, standard references or photo keys, and general and specific information about the location and disposition of friendly and enemy forces. Psychological measurement principles are built into these performance situations, and their significant characteristic as a measurement device is that they simulate the operational situation as exactly as possible.

Once having developed the prototype performance measures, we were in a position to move ahead in our research in two different ways: firstly, we were ready to tryout these measures as a means of checking their psychometric properties, and making improvements in them; secondly, and more importantly, we could initiate a number of pilot studies to assist in refining the studies and also in determining the further research value of some of our hypotheses. Since these pilot studies relate to key points in the image interpretation process, results of these studies may have immediate application in the military setting. Among the pilot studies now being conducted are investigations into the stereoscopic vs. non-stereoscopic viewing of photographs; the reliability of photo interpretation reports; the composition of PI teams, the work procedures of tactical PI units; and the influence of informational set on photointerpreter performance.

Three of these studies will be presented in two papers in today's session to provide you with a notion of the scope and diversity of the current research investigations. My talk covers two studies: (1) the value of stereoscopic viewing to photointerpreter performance, and (2) the impact of informational set on performance. In one study, the problem relates to the use of a piece of equipment; in the other, to the problem of psychological set. Mr. Sadacca, who follows me immediately, will report on team composition and work procedures.

b. Stereoscopic vs. Non-Stereoscopic Viewing

In the support of advanced reconnaissance systems, a large number of development and cost problems are incurred to secure stereo photographs. These problems are concerned with the determination of effective and economical means of obtaining, processing, annotating, printing and storing stereo photographs in data processing systems. Even within conventional photo reconnaissance systems, a substantial portion of overall cost related directly to the problem of obtaining stereo photographs over and above simple coverage. If it could clearly be demonstrated that stereo viewing contributes significantly to photointerpreter performance, then the expense for the development and use of the stereo capability is of course justified. In addition, the requirement for stereo viewing in the design specifications for radar and infrared sensors is an important ongoing problem that needs to be resolved.

Findings of a previous pilot study seemed to put in question the value of stereo viewing in the interpretation of small scale strategic photographs. These findings provided the impetus for further research to assess the value of stereo viewing within different intelligence environments. While many types of stereo studies have been conducted, none provided findings that could be generalized to real life Army photointerpreter systems.

The primary objective of the present study is to determine whether or not stereo viewing helps in the identification of militarily significant tactical and strategic objects that appear in photographs available in the operational setting. No attempt was made in this study to vary systematically such important stereo interactions as scale, resolution, and content. The present study was planned primarily to determine the need and direction for more refined research in this area.

In July and August 1960, data were collected on 59 individuals, 21 officers and 38 enlisted men, about to graduate from the Photo Interpreter course at the Army Intelligence Center. Two matched groups were established on the basis of aptitude tests and final course grades. Three sets of tactical photographs obtained during the Korean War, and one set of strategic photographs, were presented to all interpreters under simulated operational conditions. For each set of photographs, stereo pairs were provided to one of the two matched groups, and non-stereo photographs to the other. Both groups of interpreters served as either the experimental or control group for two sets of photographs. The time limits for the different measures were considered reasonable in view of the nature of the photographs and the targets the PI's were asked to locate and identify.

In addition to photographs, maps, overlays, and standard references, the interpreters were provided with a situation sheet which was read aloud to them before they began to look at the photographs. The interpreters were asked to detect and identify objects of military significance. The objects of concern were listed on a situation sheet to insure standard scoreable responses to a desired level of detail. The objects were

similar to the target types they would be required to identify in a real combat setting. They included such targets as tanks, artillery, positions, fortifications, and weapons.

In taking the tests, the photointerpreters annotated by number directly on the photographs the targets they had located, and then recorded their identifications of the targets on special answer sheets using only the descriptive terminology allowed. They also recorded on their answer sheets the confidence they felt in their identification for each target, using a three-point scale (positive, probable, and possible). In addition, at the end of every 5-minute period the examinees marked their answer sheets to indicate which responses they had made during the 5-minute period.

The keys of "ground truth" used in scoring the exercises were provided by highly experienced interpreters who availed themselves of ground survey information, historical records, photointerpretation keys, and in some cases, larger scale photographs than were used in the exercises. The subjects' Right scores consisted of the number of keyed objects correctly located and identified. Their Wrong scores consisted of the number of objects misidentified. Most of the subjects' wrong scores did not result from misidentifying the objects in the key, but rather resulted from the subjects identifying as valid targets, objects which really had no military significance.

TABLE I presents the mean stereo and non-stereo responses for all individuals for each of the four measures for the total time period allowed.

Neither the mean differences for right or wrong scores were significantly different at the .05 level. Furthermore, there was no consistent pattern or trend favoring one method or the other. Stereo responses were "better" four times; non-stereo, three times, and there was one tie. Actually the mean rights scores for the two methods were very close to one another - the largest difference being .8 for tactical measure 3 in favor of non-stereo.

TABLE I

COMPARISON OF MEAN STEREO AND NON-STEREO RESPONSES (Group A, N = 29; Group B, N = 30)

Measures	Method	Right	Wrong
T-1	Stereo	2.3	15.6
	Non-Stereo	2.3	16.7
T-2	Stereo	4.0	9.5
	Non-Stereo	4.8	8.7
T-3	Stereo	5.6	14.0
	Non-Stereo	5.4	15.7
S-1	Stereo	5.4	2.9
	Non-Stereo	5.8	4.0

- All mean differences not significant
- No consistent pattern:
  stereo better - 4 times
  non-stereo better - 3 times

This same analysis was also run for an initial time period simulating flash or immediate type reporting. About 1/3 of the total time allowed for each measure was allowed for this type of reporting. The results for this analysis did show a consistent trend in favor of non-stereo viewing for the right responses, and a consistent trend

TABLE II

COMPARISON OF STEREO AND NON-STEREO RESPONSES BY TARGET TYPE

FOR RIGHT AND WRONG RESPONSES FOR INITIAL AND TOTAL TIME PERIODS

- 138 COMPARISONS WERE MADE BETWEEN STEREO AND NON-STEREO RIGHT AND WRONG RESPONSES BY INDIVIDUAL TARGET TYPES.
- 14 OF THE 138 MEDIAN DIFFERENCES WERE SIGNIFICANT.
- NO DISCERNIBLE ADVANTAGE OF EITHER STEREO OR NON-STEREO FOR ANY TARGET TYPE.
- OF ALL THE TARGET TYPES IDENTIFIED IN THE PHOTOS, NONE DEFIED IDENTIFICATION WITHOUT STEREO.

in favor of stereo viewing for the wrong responses. However, only one of the eight comparisons were statistically signficant at the .05 level. Thus there is an indication that information of the type required in this study perhaps can be more rapidly extracted within relatively short time periods without the use of a stereoscope, and with no discernible loss of overall accuracy of interpretation.

An additional analysis was run by individual target type within each photographic set. This analysis was made to determine if stereo non-stereo differences might have been obscured by averaging all responses together. Tests of significance between stereo and non-stereo median differences for each target type within each photo set were made, both for the initial and total time periods, and for both right and wrong responses. TABLE II shows the results obtained from these comparisons.

It was found that for the 138 comparisons made, only 14 were significant at the .05 level. However, no discernible advantage could be detected for either of the two methods for any target type. It was further determined that of all the target types identified in the photos, none defied identification without stereo.

All of the findings presented concerning the value of stereo viewing must be evaluated in the light of the study setting. There are many factors that might tend to limit the generalizability of the findings including the specificity of photo-content, scale, and resolution and the nature of the questions posed to the interpreter. Nevertheless, it is concluded on the basis of these unusual findings that the contribution of stereo be studied intensively in a new series of experiments. In these new studies, photo quality and content variables should be systematically controlled. Through such studies, it may be possible to determine the specific kinds of interpreter problems and photo qualities for which stereo viewing could be profitably employed. If such selected application of stereo could be made, this would result in an enormous saving of time, effort, and money in all aspects of procuring, processing, and interpreting aerial photographs.

I would like for a few moments to direct your attention to a most important finding which we derived from the stereo study relating to accuracy of interpretation. Accuracy was found to be low -- around twenty-five percent within this study excluding consideration of omitted responses. When one considers this level of accuracy for conventional imagery, the problem of improving proficiency becomes even more critical for degraded qualities typical of radar and infrared photos.

In considering this level of accuracy, it is important to note that this is the proficiency of inexperienced interpreters working on tactical photographs. However, we obtained a similar kind of result when we examined the performance of highly experienced strategic photointerpreters. It appears that a major research effort is needed to determine means of improving performance of interpreters using conventional images as well as for determining the means of interpreting new sensors currently being developed.

c. The Influence of Informational Set on Image Interpretation

I will now briefly report on the second study. The design of the sensitization experiment, which explores the influence of informational set, is similar to the stereo study just presented. However, different performance measures were used on the same sample employed in the earlier study.

In the operational military setting, the interpreter is usually asked to provide information specific to a particular tactical problem. Before he begins the search of the imagery, he is frequently given whatever information is available concerning the targets to be located and identified. The types and sources of information available to the interpreter may vary considerably in reliability. The information may come from friendly reconnaissance patrols, intelligence agents, aerial observers, defectors, or prisoners of war. The reliability of the source may differentially affect responses of the interpreter. Furthermore, the suggestibility of the interpreter is likely to increase as the quality of the photograph -- its resolution and scale -- decreases. Suggestibility is probably a composite function of information source, information content, and the quality of the photograph -- and, of course, it should be added -- of the individual photointerpreter himself. The problem of suggestibility may become very severe when the photographic materials are poor and the reliability of the accompanying information is also poor. For example, a photointerpreter is asked to determine the presence or absence of an enemy tank battalion within a given geographic location. He is also informed at the same time that ground reconnaissance patrols have spotted enemy tank elements. Such information given to the interpreter may lead him to see tanks where there are no tanks. He may respond on the basis of doubtful cues, cues that are on the threshold of resolution. Suppose that the information provided him is in error, what is the effect of such misinformation? Under such conditions would it be better to withhold the suggestive information from the interpreter, perhaps to have the intelligence officer himself integrate the information provided independently by the PI with information obtained from other sources?

The sensitization study is a first attempt at examining analytically some of the variables that enter into the influence of suggestive information on performance. Though there are many variables that may have a bearing on the suggestion process, the present effort was limited to investigation of a comparatively small number of variables pertaining to suggestion. The primary objective was to determine whether or not additional intelligence information had an effect on the interpretation of photographs.

Three performance measures were used. Photographs of enemy positions during the Korean War were used for the tactical situations, and photographs of an urban area in Japan for the strategic situation.

As in the stereo study already described, each of the two matched groups served as either an experimental or control group for a given set of photographs. In addition to photographs, maps and overlays, the interpreters were provided with a situation sheet which was read aloud to them before they began their task. The additional intelligence information was inserted in these situation sheets for the experimental groups. The control groups were not given the sensitizing information. A typical insert that was read exclusively to the experimental group is presented:

A night reconnaissance patrol which penetrated into the area of photos 101 and 102 at 0400, 3 May 1950, reported sighting an armored reconnaissance unit consisting of tanks, 2 1/2-ton trucks, and 1/4-ton trucks. The vehicles were being widely dispersed and apparently in the process of being camouflaged with what little vegetation exists and by what appeared to be attempts at removal of track activity.

Note that the additional information directly suggests the presence of vehicles.

For this talk, we have selected the results which best exemplify the total findings. Only two sets of comparisons, one from a tactical set of photographs, the other from a strategic one, will be discussed at this time.

In the tactical exercise, the experimental group was told that a friendly patrol had seen vehicles being dispersed and camouflaged in the area covered by the photographs. Actually there were no vehicles at all in the photographs. TABLE III presents these results. The cell entries in the table represent the number of individuals in the specified group: experimental or control, for a given "Wrongs" score. Wrongs reflect errors of invention. The separation of individuals into low and high scorers was made on the basis of median scores.

As may be seen from TABLE III, after 10 minutes of examining the photography, a significantly greater proportion of the photo-interpreters in the experimental group had reported seeing more than one vehicle. The proportional difference was less at the end of the exercise and was not quite significant. Perhaps the very fact that PI's were asked to locate the targets acts after awhile to suggest the targets' presence to the control group. But, at any rate, the added information seems to be influencing the experimental group's initial performance also.

TABLE III

COMPARISONS OF VEHICLES WRONG SCORES

	After 5 Mins.		After 10 Mins.		After 15 Mins.		
Group	0	1-5	0-1	2-23	0-1	2-28	Total
Experimental	20	10	13	17	10	20	30
Control	23	6	23	6	16	13	29
Total	43	16	36	23	26	33	59
	$X^2 = 1.19$		$X^2 = 8.02$		$X^2 = 2.85$		
			$P < .01$				

TABLE IV shows the results for Wrong responses to hospitals. There the subjects had been sensitized to hospitals. Here the significance of the difference in the proportions between the experimental and control groups is greater at the end of the exercise than it was half-way through the exercise. Actually, the time limit for this performance

TABLE IV

COMPARISONS OF HOSPITAL WRONG SCORES

	After 10 Mins.		After 20 Mins.		
Group	0-1	2-9	0-2	3-13	Total
Experimental	14	16	9	21	30
Control	22	7	22	7	29
Total	36	23	31	28	59
	$X^2 = 5.28$		$X^2 = 12.44$		
	$P < .05$		$P < .001$		

measure was not considered adequate for careful examination of the 11 photographs used in the measure. It is possible that with added time the pattern or results would be similar to those obtained for the tactical set of photographs. Of course, the results may be due to differences in photographic content.

To summarize the results for all photographs, significant differences were found for 3 of the 4 targets between the performance of interpreters who had been given additional information and interpreters who did not have the information. No significant differences were found for targets which had been presented without additional information.

The positive results of this pilot study indicate, we believe, that this is an area in which much fruitful research of immediate and practical value can be conducted. Systematic examination of the effects of such variables as information source, credibility, photo quality, target type, time requirements, and the experience of the photo interpreters should be made. The results of such studies will be useful to intelligence officers in determining what information should be made available or withheld from photo interpreters to help maximize the accuracy and completeness of their identifications.

C. THE ACCURACY AND COMPLETENESS OF INDIVIDUAL AND TEAM PHOTO INFORMATION EXTRACTION by Dr. Robert Sadacca, Personnel Research Branch, The Adjutant General's Office, Washington, D. C.

In the studies just reported by Dr. Zeidner, findings were provided on problems relating to the presentation of stimulus material to photo interpreters. In this study the focus is on the problem of the utilization of photo interpreters. More specifically, this paper describes an initial investigation into the effects of varying the number and composition of interpreters in PI teams and the work methods the teams employ.

In the operational tactical setting, interpreters function in units which are generally headed by an officer, who himself is a photo interpreter. Work assignments are made on the basis of such factors as the number of available personnel and the importance and urgency of the desired interpretations and thus may vary from situation to situation. In some cases individuals are assigned to work independently on separate sets of photography. In other cases teams may be formed to jointly examine imagery for critical targets. Preliminary findings from a number of pilot studies indicate that the performance of the individual photo interpreter in terms of accuracy and completeness of information extraction is far from perfect. The question arises, can the intelligence product of photo interpreters be improved by having more than one interpreter examine the imagery and, if so, what is the best method for going about combining the efforts of a number of interpreters? For example, should the interpreters work completely independently and have their responses pooled by the air intelligence officer, or should they cooperatively examine the imagery discussing their interpretations as they go along, or is some combination of independent and cooperative effort the optimal procedure?

The possibility of utilizing interpreters in teams to obtain information is one that perhaps comes to mind as a matter of course. However, there is a fundamental basis for looking at this problem that holds

TABLE I

PATTERN OF RESPONSES FOR TWO INTERPRETERS:

WORKING INDEPENDENTLY
(Methods I and II)

INTERPRETER j

INTERPRETER i	RIGHTS	OMITS	WRONGS	Σ
R	R_{ij}	R_iO_j	R_iW_j	R_i
O	O_iR_j	O_{ij}	O_iW_j	O_i
W	W_iR_j	W_iO_j	W_{ij}	W_i
Σ	R_j	O_j	W_j	

TOTAL SCORES

$R_T = R_i + R_j - R_{ij}$ (Method I)

$W_T = W_i + W_j - W_{ij}$ (Method I)

$R_T = R_{ij}$ (Method II)

$W_T = W_{ij}$ (Method II)

out the promise of real improvement in performance and, at the same time, may help determine how this pooled information is best obtained. This relates to the concept of the correlation of performance between individuals.

Let us consider this concept of the correlation of photo interpreter performance in some detail. TABLE I shows the performance of photo interpreters i and j broken down into three categories: their Right interpretations, their Wrong interpretations and the targets on the imagery which they failed to report, that is, their Omits. Now let us assume these two photo interpreters worked completely independently. Then the number of targets which they both got right can be represented by R_{ij}, in the upper diagonal cell. Similarly, those targets which they both misidentified can be represented by W_{ij} and the targets which they both omitted by O_{ij}. Now the targets which interpreter i got right but interpreter j omitted can be represented by R_iO_j in this cell and R_iW_j represents the targets which interpreter i got right but which interpreter j misidentified, for example, suppose he called a tank a bunker. The other correlation elements in this little matrix are similarly defined.

Now, if there were perfect agreement between the responses of the two photo interpreters every Right response made by interpreter i would also have been made by interpreter j and the same would hold true for Wrong responses. Another way of putting this is that when the correlation between the performance of i and j is perfect or equal to one, all the off-diagonal cells disappear. Perfect agreement, however, is obviously not what we are looking for when we wish to pool independent responses. For if the two interpreters agreed completely to begin with, there would be little point in combining their responses because we would still have the same number of Rights, Wrongs, and Omits as we had for them separately.

Now, there are two fundamental purposes involved in combining the efforts of individuals. One is to maximize the number of correct target identifications, that is, to increase R at the expense of O. The second purpose is to minimize the number of wrong identifications, that is, reduce the number wrong, W, to zero, if possible. These two purposes can unfortunately work at cross purposes. For, as you shall see, the method of combining the efforts of individuals which we believe maximizes the number of right identifications also unfortunately tends to maximize the number of wrong identifications. Similarly, the method which we believe will minimize the number of wrong responses may also tend to minimize the number of right responses.

It might be thought that the way out of this dilemma is to set the fundamental purpose of combining individuals' efforts as that of maximizing the ratio of rights to total number of responses, which is the standard way of measuring accuracy. But would this completely solve the problem? Can we say, for example, that a method which yields 4 right targets and 1 wrong target for an accuracy of 80% is better in all circumstances than a method which yields 30 right targets and 20 wrong targets for an accuracy of only 60%. Much obviously depends upon the intelligence requirements of the military situation, as to whether the commander can tolerate more misidentifications in an effort to get the maximum number of targets correctly identified, or whether he must be very sure of his targets at the expense of missing some.

So as the various methods of utilizing PI's used in this study are discussed on theoretical grounds and when data are presented which support these theoretical considerations, it should be kept in mind that the optimal method for using PI's in teams may vary with the intelligence requirements of the military situation.

Four methods of combining the efforts of team members were explored in this study. In Method I, the PI's comprising the various teams worked completely independently during the exercises and had their separate responses pooled later. Now the total number of right responses, R_T, made by photo interpreters i and j combined is $R_i + R_j - R_{ij}$. (R_{ij} is subtracted because otherwise it would be counted twice). Similarly, W_T, the total number of misidentifications is $W_i + W_j - W_{ij}$. The value R_T obtained by Method I represents all the targets that the two PI's found and thus Method I can be expected to produce the maximum number of correct identifications that could be obtained in a fixed time period from combining the efforts of photo interpreters. Unfortunately, however, this method also combines the wrong identifications of the interpreters, doing nothing to screen them out in any way. Therefore, we might also expect Method I to produce the largest number of wrong identifications, and to make for a team accuracy level slightly lower than that of individual PI's.

Method II also utilizes teams comprised of PI's who worked completely independently, but pools their responses in a different way. In Method II, only identifications which the two interpreters agreed upon are considered as having been made by the team. Thus the team right scores are restricted to the R_{ij} entry in this two man case. As R_{ij} cannot be larger than either R_i or R_j, R_{ij} is almost certain to be smaller than R_T of Method I. However, by the same reasoning one would also expect W_{ij}, the team's wrong score by this method, to be much less than W_T of Method I. Now whether the accuracy of Method II will be higher than Method I's accuracy depends upon whether photo interpreters tend to agree more on their right identifications than on their wrong identifications. Since it is more reasonable to suppose that photo interpreters will tend to agree more on targets that are actually present than they will agree on targets which are not present, one would expect proportionately more rights to survive the agreement criterion than wrongs, and hence the accuracy of Method II should be above that of Method I. Supporting this reasoning are data from another study which indicated that the more PI's who agreed on the presence of targets, the higher was the probability that they were correct.

TABLE II

PATTERN OF RESPONSES FOR TWO INTERPRETERS:

WORKING COOPERATIVELY
(Methods III and IV)

INTERPRETER j

RIGHTS OMITS WRONGS

INTERPRETER i

$$
\begin{tikzcd}
\text{R} & R_{ij} & R_iO_j \arrow[l] \arrow[d] & R_iW_j \arrow[l] \arrow[d] \\
\text{O} & O_iR_j \arrow[u] \arrow[r] & O_{ij} & O_iW_j \arrow[l] \arrow[d] \\
\text{W} & W_iR_j \arrow[u] \arrow[r] & W_iO_j \arrow[u] \arrow[r] & W_{ij}
\end{tikzcd}
$$

In Methods III and IV instead of working independently the PI's worked in teams while examining the imagery. Each member of a team was given complete sets of photography but only 1 answer sheet was given to a team. The team members were instructed to put on their answer sheet only those identifications which both members of the team agreed upon in the case of 2-man teams and which at least 2 members of the team agreed upon in the case of 3-man teams. In both Method III and IV the team members could freely discuss their identifications and could go about cooperating in any way they desired.

Method III differed from Method IV in that in Method III the interpreters worked completely independently half of the time, and during the other half of the time, got together and went over each others' identifications. In Method IV the interpreters worked together for the entire period of time. In both methods the team members could freely discuss or argue about their identifications.

It is to be expected that as a result of their discussions, the PI's will tend toward agreement on some targets that they previously disagreed upon. TABLE II shows the expected effect of this agreement on the elements involved in photo interpreter performance correlation. We see a general movement from the off-diagonal cells to the diagonal cells and as indicated by the heaviness of the arrows relatively more agreement on right responses than on wrong responses. Consider, for example, targets R_iO_j, which interpreter i saw but which interpreter j did not see. When the interpreters compare their identifications interpreter j's attention will be specifically brought to these targets. Considering that the targets are really there and that his teammate is arguing for them, the chances are that these targets will tend to wind up in the R_{ij} cell rather than being omitted. We would expect therefore, that there will be considerably more agreement upon right responses for the cooperative Methods III and IV than for Method II, but owing to the fact that some right identifications will not be agreed upon, the *total number* of rights from these cooperative methods will be less than for Method I, which pooled all right responses of the team members.

The same, in general, holds true for the wrong responses, but here one would expect more tendency for wrong identifications made by only one interpreter to drop out, as the other interpreter would probably be more resistant to agreeing to misidentifications. As a matter of fact there is evidence from another pilot study that interpreters are more confident of identifications that are later scored right than they are of their wrong identifications, so that there is a good chance that the interpreter making the wrong response will not argue as strongly for it as he will for his right responses. It is to be expected then, that the wrongs will be fewer in number than would be obtained by Method I and that although the rights would also be fewer, the over-all accuracy would be improved although not as much as was the case for Method II, where there is no opportunity for teammates to induce each other into agreeing to misidentifications.

In order to obtain empirical data relevant to these considerations, two sets of tactical photographs obtained during the Korean War and one set of strategic photographs were presented to 30 teams comprised of officers and enlisted men about to graduate from the Photo Interpreter course at the Army Intelligence Center. Five types of teams varying in size and composition were formed. The five types of teams were (a) two officers; (b) two enlisted men; (c) one officer and one enlisted man; (d) one officer and two enlisted men; and (e) three enlisted men. These particular types of teams were selected for investigation as they are the types most likely to be found in field PI units.

In forming the teams, care was taken to match them on the basis of the average aptitude and final course grades of their members. Two teams of each type, or 10 in all, took the three performance measures under each of the three basic conditions: the independent, the independent-cooperative, and the cooperative. The scores of the 10 teams that worked under the independent condition were obtained under both Method I (combining all team members' responses) and Method II (combining only agred upon responses). The teams were given 1 hour to complete each performance measure. Along with a complete set of photography, each team member was given maps of the relevant areas and sortie plot overlays. The target requirements and instructions were identical for all teams with the exception of those instructions dealing with the team work method.

As can be seen in TABLE III the total number of targets correctly located by the various teams for all three performance measures *combined* differed significantly at the .01 level, depending upon the work method employed by the teams. The mean right for Method I, which combined all the responses of independently working team members was 14.4, while for Method II, where only the agreed upon responses were pooled, only about a third as many targets were correctly identified on the average. The performances in terms of right identifications of the 10 teams working under the half independent-half cooperative method and of the 10 teams working under the completely cooperative method fell in between those of Method I and II, and were higher than the mean right of the individual PI's who worked independently. The relative rankings of these performances are consonant with the expected results outlined earlier.

Notice that the team types did not differ significantly in number of right identifications. One might expect the three-man teams to do better than the two-man teams, since the additional man might find some targets the other two men did not find. Although the mean rights for the three-man teams came out slightly higher than those of the two-man teams, this difference is nowhere near significant.

TABLE III

ANALYSIS OF TEAM RIGHT SCORES FOR ALL PERFORMANCE MEASURES

METHODS

	I	II	III	IV
MEAN RIGHT	COMBINED IND. 14.4	AGREED IND. 4.8	IND.-COOP. 10.9	COOP. 12.9

TEAMS	MEAN RIGHT
OO	12.2
EE	8.9
OE	9.5
OEE	12.4
EEE	10.8

Source	d.f.	Mean Sq.	F	P
Methods	3	177.9	6.1	< .01
Teams	4	19.9	.7	--
Interaction	12	10.8	.4	--
Within Cells	20	29.4		

Mean Right of Individual Interpreters = 8.4

Significant differences were observed, however, between the two and three-man teams in the number of wrong responses made. TABLE IV, perhaps contrary to expectations, shows that the three-man teams made significantly more misidentifications than the two-man teams. Perhaps, in the cooperative teams, the presence of a third man to act as arbiter enabled differences of opinion to be resolved too easily, without critical evaluation of the stimulus material.

As anticipated, Method I produced by far the greatest number of wrong responses. That PI's working independently do not tend

TABLE IV

ANALYSIS OF TEAM WRONG SCORES FOR ALL PERFORMANCE MEASURES

METHODS

	I	II	III	IV
MEAN WRONG	115.3	11.1	41.3	41.8

TEAMS	MEAN WRONG
OO	42.4
EE	43.2
OE	52.9
OEE	57.4
EEE	66.0

Source	d.f.	Mean Sq.	F	P
Methods	3	19,658.9	73.7	< .001
Teams	4	788.3	3.0	< .050
Interaction	12	176.6	.6	--
Within Cells	20	266.7		

Mean Wrong of Individual Interpreters = 53.5

to agree on wrong responses, is evidenced by the mean wrong of only 11.1 obtained for Method II, which is about 10 times lower than that of Method I and about 4 times lower than the cooperative methods, III and IV. Also, as was anticipated, the cooperating teams made fewer wrong responses on the average than the individual PI's working by themselves on the imagery. Team members could evidently talk one another out of some wrong responses.

The average accuracy levels or percentages of right over total responses achieved by the teams working under the four methods

TABLE V

ANALYSIS OF TEAM ACCURACY FOR ALL PERFORMANCE MEASURES

METHODS

	I	II	III	IV
MEAN %	COMBINED IND.	AGREED IND.	IND.-COOP.	COOP.
	11	34	22	25

TEAMS	MEAN %
OO	30
EE	19
OE	25
OEE	25
EEE	16

Source	d.f.	Mean Sq.	F	P
Methods	3	8.4	3.4	< .05
Teams	4	2.4	1.0	--
Interaction	12	1.3	.5	--
Within Cells	20	2.5		

Mean Accuracy of Individual Interpreters = 12%

were again significantly different and in the expected direction, as shown in TABLE V. Method I produced an average team accuracy level slightly lower than the average accuracy of the individual PI's. Method II's accuracy level was highest whereas the average accuracy levels of teams working under Methods III and IV fell in between. Although there were significant differences in the number of wrong responses between 2 and 3-man teams, the average accuracy levels of the five types of teams did not differ significantly. There may, however, be a slight tendency for officer-led teams to be more accurate than teams consisting only of EM's. More data, however, are needed to test the significance of these differences.

In summary, significant differences were obtained in this pilot study between different methods of combining the efforts of a number of interpreters. The four methods tried yielded differences in the number of targets correctly identified, the number of targets misidentified, and the accuracy levels of the teams using the different work methods. As anticipated, the method of pooling all team members' independently-made responses yielded the most correct identifications, but also produced the most misidentifications and the lowest accuracy. The method of pooling only agreed upon responses yielded the highest accuracy and the fewest wrongs, but also the fewest rights. The methods involving cooperation among team members produced intermediate levels of right, wrong, and accuracy scores. There were no significant differences between the half-independent and half-cooperative method and the completely cooperative method although both cooperative methods produced better performance than PI's working alone.

It should be emphasized that although in this study, teams of PI's were shown to do better on the whole than individual PI's, there is still much room for improvement in team performance. The best performing team over-all, had an accuracy level of only 57%. Much additional experimentation needs to be done, varying the size and composition of PI teams and the work methods they employ before final solutions are obtained to the problem of combining the efforts of a number of photo interpreters to improve their intelligence product. However, as was pointed out earlier, the intelligence requirements of the military situation, the relative importance of identifying the maximum number of targets as against avoiding a large number of misidentifications, should determine which method the CO of a PI unit uses to combine the efforts of his team members.

D. U.S. ARMY PARTICIPATION AT THE U.S. NAVAL TRAINING DEVICE CENTER by Dr. Kenneth F. Thompson, U.S. Naval Training Device Center, Port Washington, Long Island, N.Y.

1. Human Factors Engineering for Development of Training Devices.

The Army Participation Group of the U.S. Army Continental Army Command at the U.S. Naval Training Devices Center represents a very interesting and effective collaboration between the Army and the Navy in the use of the skills and the organization

of the Training Device Center and its staff of approximately 600 people. Since I expect that there is a considerable proportion of the audience who are not acquainted with the Center, I should mention that it is located in Sands Point, New York, on the north shore of Long Island on what was formerly the Guggenheim estate.

The function of the Army Participation Group and its mission are outlined in Army Regulation 350-15, but briefly the participation group represents the Army in the design and procurement of training devices for use by the Army. A quick functional summary indicates the functions of the Center to disseminate information regarding training devices that are available, to design and produce new devices as required, to give assistance in the utilization of these devices, support the devices logistically and, last but not least, to study training problems for the purpose of assuring optimum integration of training devices into the solution of training problems. As is recognized in the official motto of the Center, ''Tools for More Effective Training'', the Center's efforts are directed toward providing devices to aid in the training process. We have as yet, even with out work on teaching machines, no expectancy of replacing the skilled and devoted instructor.

While I do not intend to attempt a hard and fast definition of a training device, I feel that it is important to note that these devices are many and varied, ranging from the extremely simple to the extremely complex. Let me briefly review a few of the Army sponsored devices that are products of the Center to give you some idea of their variety. One item, for example, is a nuclear fire marker, which simulates a nuclear explosion. In comparison with the true nuclear explosion, the nuclear fire marker costs less than $20 a shot, requires no extensive range preparation, no expensive shipment of troops to a nuclear demonstration area, simulates the nuclear explosion without radiological hazard and, with its companion devices, gives an effective simulation of a nuclear explosion, including radiological monitoring of the site of the explosion. As I have just said, an important part of the training in nuclear explosion consists of the training of radiation monitoring teams. By the use of a low powered, low frequency transmitter and a simulated radiation monitor, we can broadcast a simulated radioactive ground area, which will permit the safety monitoring team to map the area for radiological hazards after the explosion of the nuclear fire marker. The radiation monitor is identical to the service monitor, in fact, so similar that its plastic case has to be dyed a special color to distinguish it from the service monitor. Included in its kit are very small transmitters, which will give indications of local radiological hot spots.

Of more immediate human factors interest, we have developed a helicopter flight trainer built as part of a feasibility study to determine the problems involved in the visual simulation of the real world for the purpose of training helicopter pilots to fly through the use of a simulator. I might state that the results of the feasibility study were successful in underlining a number of the factors involved in this sort of simulation. I repeat that the <u>feasibility</u> study was successful, but this particular version of the <u>trainer</u> was not because of the extremely difficult technical problems involved in projecting not only the terrain beneath, but the horizon and sky above the simulator. This first attempt produced a rather interesting but unfortunate by-product; namely, that there was a strong positive correlation between helicopter flying experience and the tendency to become airsick. This latter tendency was so strong that few experienced helicopter pilots could fly the simulator for more than a few minutes without becoming profoundly nauseated. Beginners had no great difficulty in this regard. As nearly as we can determine, the reason for the sickness phenomenon centered around the technical inability to provide a completely continuous transformation in the perceived rates of rotation of the ground mass and the air mass, with the result that there were bands on which the area just above the horizon appeared to rotate at a speed that was out of scale with the rotation of the land mass. Here we have quite literally a case where too much knowledge was a dangerous thing.

A training aid which is probably familiar to all of you is the functional illustration used by an instructor to teach the functions of the 45 caliber automatic pistol. You will recall that this conventional picture gives you a view of the pistol in cross-section, and, through the use of numbered arrows, the instructor is able to run through the nomenclature of the various parts of the pistol and show the students a view of the weapon that would be literally impossible for them to get by looking at the physical pieces themselves. You will note, however, that it is only through a sequence of such cross-section drawings and considerable abstract visualization that it is possible for the student to visualize these parts in motion.

Compare this with the utility of teaching the functioning of a pistol through an operable transparency. In the static picture quite literally nothing works without considerable imagination on the part of the trainee and a good deal of hand waving on the part of the instructor: the motion and the inter-relations of various parts are extremely difficult to convey. In the operable transparency, we can move the slide back and demonstrate

that the locking lugs of the barrel are pulled out of their mating gooves in the slide. We see the slide pushing the hammer back and we see the round being ejected. Following this we see the next round being positioned by the magazine, the operation of the round being chambered and finally the locking lugs in the barrel being cammed into place into the slide once more. The function of the sear disconnector and the grip safety are clearly visible. One of the oldest devices in this field of operable transparencies, the transparency of the 45-caliber automatic pistol is one of the most popular. Approximately 500 of them have been made for the Army, Navy and Marine Corps, of which the Army has received about 100.

Through the past three samples of training devices, we have had an opportunity to see that training devices themselves offer three general advantages - economy, safety and training effectiveness since they are designed to meet these specific criteria. Now let us turn to a subject of more interest to this audience, that is the research program of the Center. Our research programs, particularly in human factors, deal with both the research and development necessary for the implementation of training device requirements and the Navy sponsored supporting research program.

Human factors engineering is a rapidly growing discipline of constantly increasing importance for the military services. I think we would all agree that the human factors engineer would be the first to confess that the bulk of his work is done to fill the gaps in our understanding of the elements we should know about the human in both training and operational situations. I feel that we would all agree that there still lies ahead of us years of work before we can begin to specify the important parameters about which we need to know in order to accomplish optimally effective human factors engineering. Now in many of the regimes of research in this area, our lack of knowledge is due to lack of available research manhours or lack of appropriately sensitive experimental methodologies. One other area, however, has been the lack of funds or opportunities to put together large research tools which would permit an entry into areas of research that would allow us to manipulate environments, so that we can collect appropriate data.

My final remarks relate to a research tool that offers tremendous potential for better statements of required parameters in the design of complex trainers. The interest in these trainers originates in the simulation problems connected with the design of operational flight trainers.

Operational flight trainers, as you may be aware, are trainers that carry the simulation of an aircraft cockpit to its present limit so that every instrument, every switch and every item of equipment in the cockpit works exactly as it does in the aircraft. In fact, these trainers are so expensive that, with the exception of the submarine simulators, very few agencies have ever had money enough to investigate their application to more mundane vehicles such as tanks, trucks and automobiles. If I cast my review of these research tools in the language of operational flight trainers, please keep in mind that, outside of the cost, there is no reason why these trainers should not be equally useful for the training of the operators of almost any vehicle. Now while admittedly Army military aircraft are generally somewhat less complex than Navy or Air Force aircraft, they all share the difficulty that in the design of the related trainers no one has more than a vague notion of what the pilot must have in terms of input information to get the optimum amount of training from the operational flight trainer. These trainers have been designed by engineers who, unable to get statements of parameters from the psychologists that would permit them to simplify the design and construction of such a complicated mechanism, were forced to come as close to total simulation as the state of the art would permit.

Figure 1 shows one of our engineers seated in the cockpit of UDOFTT, (Universal Digital Operational Flight Trainer Tool), and figure 2 shows the console for this flight trainer. UDOFTT was designed specifically as a research tool to investigate the possibilities of the digital operation of flight trainers rather than the analogue computation of the flight equations. Prior to UDOFTT all flight trainers were based on electromechanical analogues of the flight equations of the aircraft they represent. This quite literally meant that a network of servos, resistors and condensors, integrators, etc., were literally matched term for term with the mathematical equations describing the flight of a particular aircraft. UDOFTT, using digital computation, takes its equations from a deck of punched cards. Reprogramming UDOFTT for any airplane, or for a variation in flight equations, consists in loading the computer with another deck of punched cards. By contrast, the analogue computer literally had to be junked if any major changes in the equations were to be made.

Mathematical description of the flight characteristics of an aircraft have now been developed to a pretty fine point. Figure 3 is a block diagram of one portion of a set of the flight equations. The box that has been circled would generate the more refined flow diagram shown in figure 4 and the circled box of figure 4 would generate a flow diagram of equal complexity before we could finally program the first box in sub

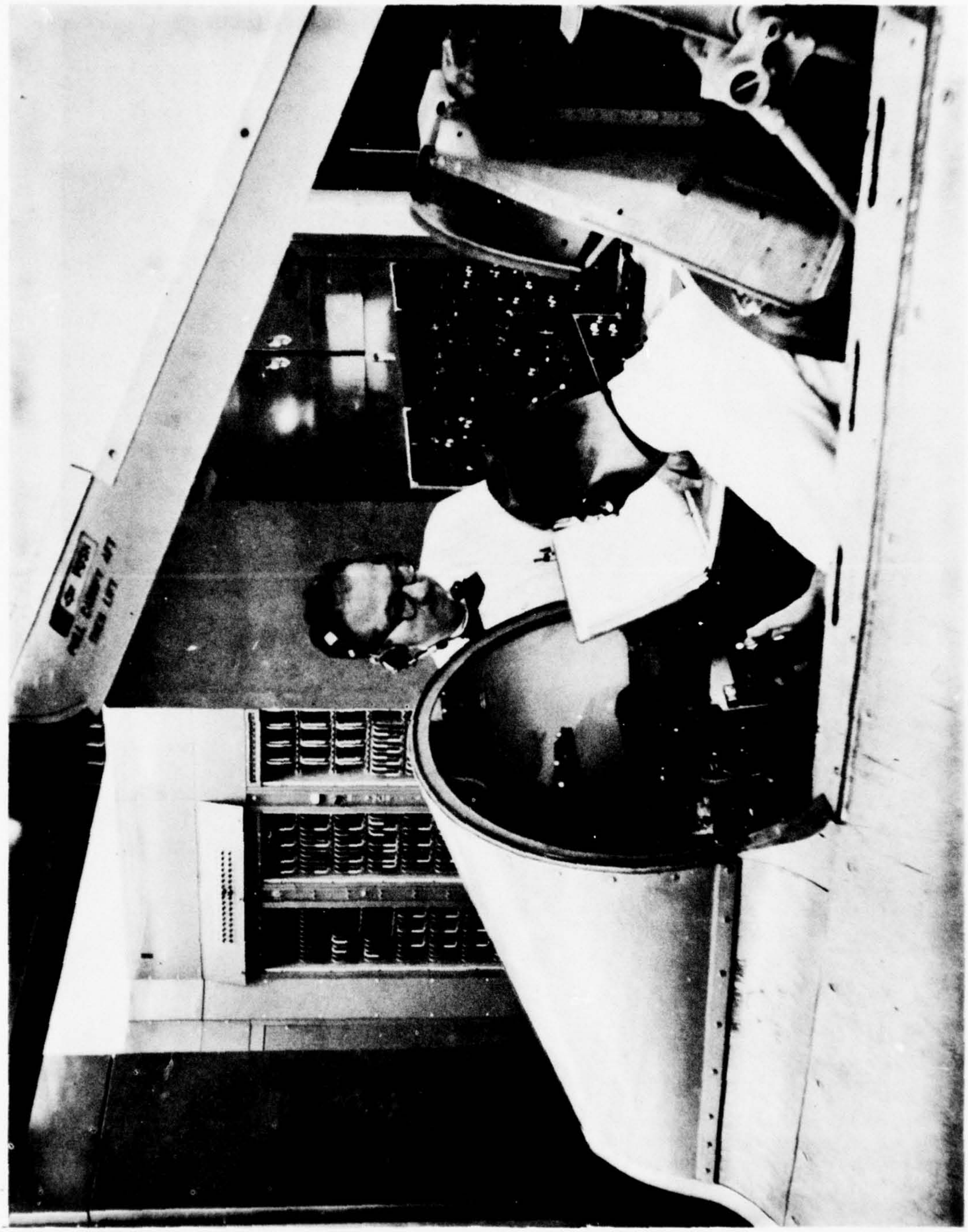

Figure 1. The UDOFTT Cockpit.

Figure 2. UDOFTT console

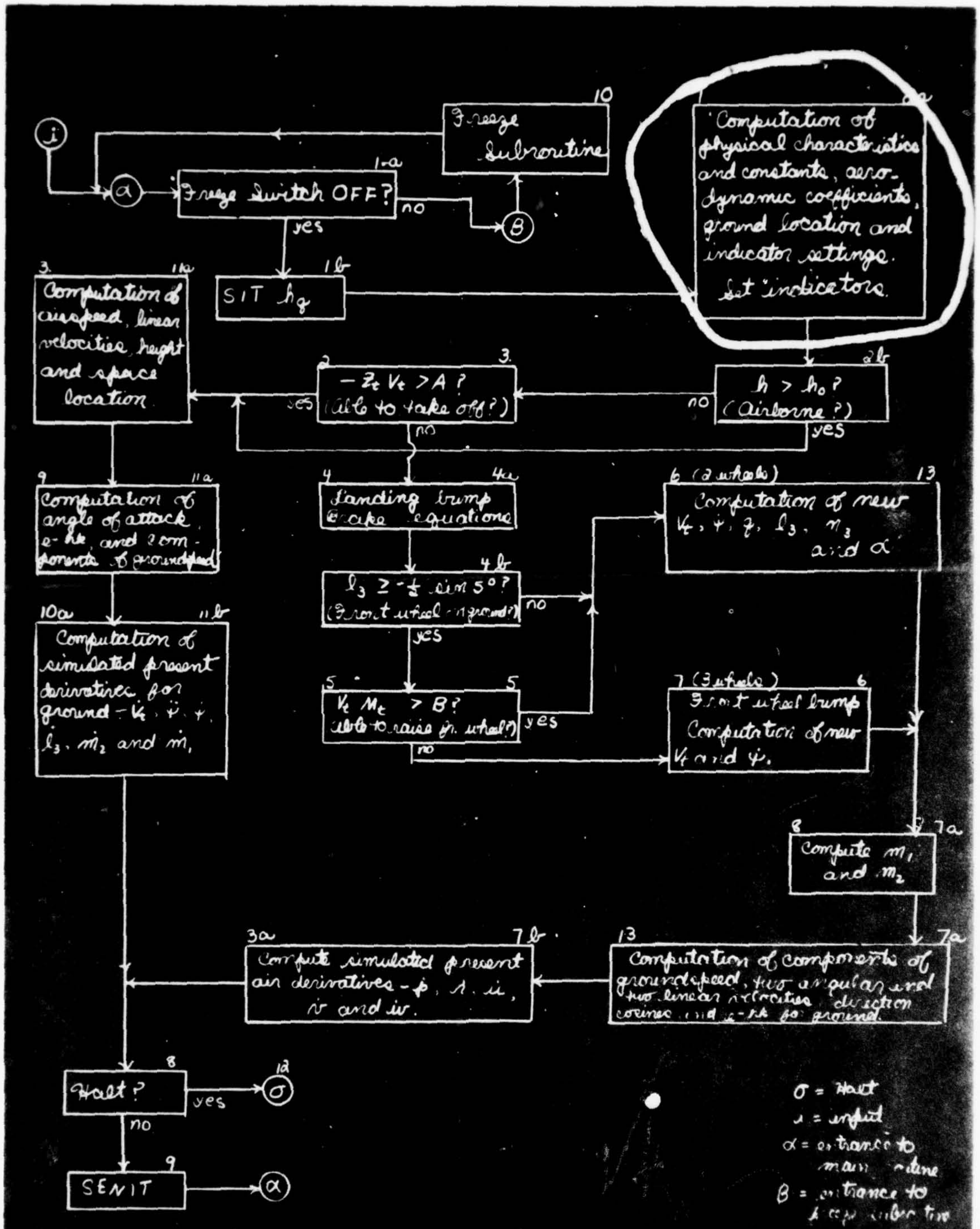

Figure 3. Flight equation block diagram

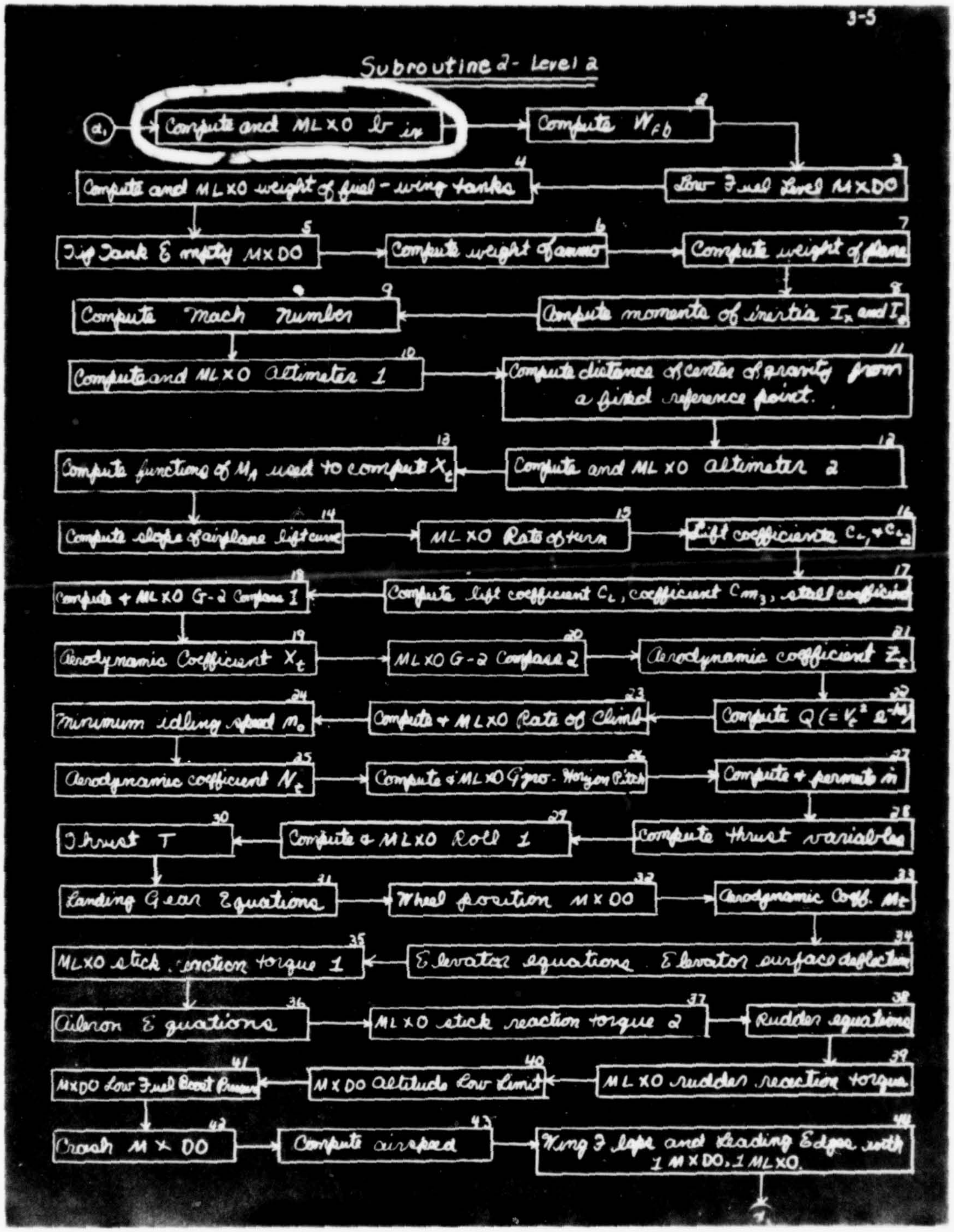

Figure 4. Block Diagram expanded

routine 2 level 2. Families of equations like this show quite dramatically why operational flight trainers with any degree of sophistication are million-dollar devices. With the advent of UDOFTT we are now for the first time equipped with a facility that would permit us economically to reprogram a flight trainer for the purpose of investigating the parameters as set by the pilot - not the parameters set by the engineer. It is expected that within this fiscal year a research program will be initialed permitting us to test out the need for all of the terms in these flight equations. For example, in the equations of figures 3-4, we should be able to determine behavioral parameters through experimentation so that, hopefully, we can eliminate many of those terms whose functions make no difference to the pilot. If we can reduce the number of terms in these equations, we can correspondingly reduce the cost of the flight trainer which would permit a large step forward in the design of such trainers. We can alter the sensitivity of the controls, we can alter the response of the aircraft, we can alter the response of the instrumentation of the aircraft almost at will with relatively simple reprogramming of the computer.

2. Supporting Research Program of the U.S. Naval Training Device Center

Two important functions of the Naval Training Device Center are: to improve the effectiveness of the Naval, as well as Army, training programs through the conduct of research leading to the development of training devices; and to study training problems as they may relate to training devices. It is within this framework that the Human Engineering Department operates.

The Human Engineering Department, however, is not only concerned with the design and layout of training devices but is also responsible for determining training requirements, functional characteristics of devices, and in some cases, for providing evaluation and utilization data on training programs.

To accomplish its mission, the Department engages in two major categories of research. One is of the specifically applied type and is oriented toward a particular training situation. For example, research has been undertaken to provide human factors data for the design of a ZEUS missile systems trainer. In other cases, considerable attention has been given to the design of ASROC and SUBROC trainers as well as specific submarine simulators.

The second type of research with which the Human Engineering Department is concerned is referred to as supporting research. Supporting research is also applied research but does not limit itself to specific training situations. It is interested in problems which arise in a variety of training situations, or which may be common to a class of trainers. For example, the problem of training radar and sonar operators arises in many military systems. Consequently, a program of research has been implemented to study the problems involved and to provide recommendations for the training of these personnel.

Other applications of supporting research have been made in problems of training for maintainability of equipment, for decision-making functions, for performance under stressful conditions, for team training, for tracking training, for training with self-instructional devices and a host of others.

At this time, I would like to describe more fully one important supporting research program and to illustrate its application to the design of training devices.

Tracking appears in a wide variety of military tasks such as following a radar blip, steering a submarine, driving a tank or in aerial gunnery, and its importance in military operations cannot be over-emphasized. Consequently, a program of research was initiated to improve human military performance through devising techniques and devices for training students in the development of tracking skills.

A preliminary investigation of tracking training by Dunlap and Associates resulted in a categorization of tracking tasks, the development of a descriptive model of tracking behavior designed to encompass all tracking tasks and the development of a group of hypotheses concerned with the transfer of training in vehicular tracking tasks.

As a follow-up to this area, by applying the preliminary findings to a representative tracking task, namely, submarine depth control, the researches found that several hypotheses previously formulated about tracking training were verified, while others were rejected. The major findings indicate:

a. The most important single factor in acquiring tracking skill appears to be practice. Thus, high levels of tracking skill may be developed relatively independently of intellectual comprehension of the dynamics of the tracking system.

b. Wide variations of the system equations in the equipment did not affect relative tracking skill to any significant degree. That is, large changes in the tracking task did not appreciably affect tracking performance.

These findings permit the generalization of recommendations to any vehicular tracking task, including submarine depth-keeping and steering. The recommendations are: (1) trainees should be given as much practice on a training device as possible in preference to lectures or classroom work; (2) training by lectures is of limited value

and should be used only to provide an adequate insight into the over-all purpose and character of the tracking task; and (3) the training device does not have to simulate the complete system in order to be effective. Adequate simulation of the system dynamics should be done but precise simulation of controls, displays and task environment is not necessary.

It should be noted that, since tracking performance was only slightly affected by sizeable changes in the system equations, significant positive transfer may occur from one complex tracking task to others.

At about this same time, another study was undertaken by the Electric Boat Company on the extent and character of the simulated dynamics necessary to develop skilled submarine operator performance. The purpose of this study was to compare the effectiveness of training devices having various degrees of simulation of an operational task. The task selected for study was one-man control in course and depth of a high-speed submarine. The performance of depth changing only, course changing only and simultaneous depth and course changing were measured under five different levels of fidelity of simulation. One group of men was trained at each level of simulator complexity.

From this study, it was possible to determine how effective was the training on each of the four simplified simulators. The results showed that training on a relatively inexpensive and simple submarine simulator permits trainees to transfer effectively to a much more complex and expensive simulator. There were no statistically significant differences between the groups trained on various degrees of simulation. However, there was a general trend for proficiency to be greater for the groups trained on the more complex simulators.

For training device design, this study provides valuable information on the degree to which an operational situation can be simulated for effective training to occur. Such information is particularly vital where cost is a limiting factor. The data suggest that while training effectiveness increases with increasing cost, it does so in proportionally smaller amounts. Thus, a few dollars added to the cost of simple simulators tend to increase training effectiveness to a much greater extent than the same amount added to the cost of a more complex and expensive simulator.

We then began to suspect that tracking skill is not really specific to particular systems, but includes both general and specific components. Increases in skill with training appear to depend not only on mastering a given vehicle, with its particular indicators, controls, and dynamic chracteristics, but also on the growth of a general psychomotor skill, resulting in better operation of a wide range of vehicles. It was believed that such a general tracking skill might best be developed by an inexpensive trainer designed to represent a wide range of tracking systems, that is, a general tracking trainer.

Experiments were conducted to determine the existence and nature of a general tracking skill or skills. One problem studied was the assessment of the degree of transfer from one simple general program of tracking training to three different specific tracking systems. The equipment gave practice on slow and fast one-dimensional tracking systems, for which stability was varied, becoming more unstable as skill increased. Then the trainees were tested on three conditions: (1) stable submarine-like condition; (2) unstable submarine-like condition; (3) aircraft condition (jet aircraft altitude control system with disturbance functions). These systems were simulated on an analogue computer.

The results demonstrated that the general tracking training established a considerable amount of skill which was transferred to the three test tasks, confirming the hypothesis that general tracking training produced important increases in skill in the control of systems having widely different dynamic characteristics. These increases in skill are probably equal to or better than that which would occur with specific training on the test (operational) systems. It is surmised that general training gives an additional profit, in that a skill developed through general training has a very broad base, and might in the long run prove more valuable to, say, a pilot who will fly many varieties of aircraft in his lifetime than would any specific tracking skill, no matter how highly developed it might be.

Evidence confirms that vehicular training has very wide transfer value. Whether this is truly due to a cluster of human abilities that could be called a generalized tracking ability requires further validation. However, if further work does validate this hypothesis, it would permit the development of tracking trainers of a more universal nature with consequent wide utility in teaching fundamental tracking skills. Conversely, the expensive development of specific tracking trainers could be reduced.

Under contract, the Center is presently developing a prototype version of a Generalized Tracking Trainer. Plans are being formulated to conduct validation studies to determine how well training can be transferred from the trainer to performance in operational situations. For this purpose, studies will be conducted on submarine diving performance at the Submarine School in New London as well as on fixed wing aircraft at Ft. Rucker, Alabama.

We have seen the evolution of a supporting research project which has resulted in the development of a training device. However, all research projects do not have this ideal result of immediate implementation in the form of hardware. Many others supply guidelines or principles for the design and utilization of training devices. In either case, the objective of the supporting research program is fulfilled, namely: to improve human military performance that is required by current operational situations by incressing the effectiveness of training devices and techniques. The objectives, of course, can only be met to the extent to which the research findings are incorporated into the design of training devices.

CHAPTER 10

A LONG-RANGE VIEW OF RESEARCH IN MILITARY PSYCHOLOGY AND SOCIAL SCIENCES

A LONG RANGE-VIEW OF RESEARCH IN MILITARY PSYCHOLOGY AND SOCIAL SCIENCES

an address by Dr. Charles W. Bray, Research Group in Psychology and the Social Sciences
Smithsonian Institution

What are the general targets of long-range research in military psychology and social science? What areas of psychology and social science are relevant to defense needs and "ready" for major advance? How are these research topics supported by the military establishment, today? Is present Defense support of long-range research optimally calculated to produce major advances in the ready areas? Are new kinds of support needed?

These are the questions to which I wish to address myself tonight. Dr. Baker's kind invitation to speak to you gives me an opportunity to register my personal opinions on these subjects -- opinions which have been slowly maturing in the past year and a half at the Smithsonian -- a period spent in reading and in consultation with America's leading military psychologists and social scientists. Although I have reason to believe that many of my colleagues, many of you, share many of my opinions on these difficult questions, I wish to repeat that, tonight, I speak for myself alone, not for the Smithsonian or for my colleagues.

First, then, what is the goal of research in military psychology and social science? How can we define the objectives, beginning with the overall, general objective, and moving to particular objectives as we define those specific programs which seem to hold out the greatest promise of helping the military establishment.

I begin with a negative statement. At present, the behavioral sciences seem to hold out no promise of particular "breakthroughs." Nevertheless, even in these times when there is a tendency to undervalue any research which will produce less than an atom bomb, a conquest of space, or some other near miracle, the products of long-range behavioral science research are worth shooting for. They will be increases in significant, general capacities, such as the capacities to:

1. Lead men to work effectively.
2. Plan how to use men.
3. Adapt machines to men's needs and purposes.
4. Create effective teams of men.
5. Coordinate, direct, plan the Defense organization, and adapt it to changing conditions.
6. Adjust Defense activities in terms of their probable impact on the attitudes, opinions, and actions of people, friendly, enemy, and non-committed people, outside the Department of Defense.

In all these respects, behavioral scientists are ready in a ten-year period to increase Defense capacity.

The general form of the research target, then, is to lay the basis for an overall increase in the sophistication and inventiveness of Defense management of people. There has been a growing recognition in the past few years that management sophistication and management inventiveness about people are as much the key to Defense success as any other item. For several generations, we Americans have been justifiably proud of our sophistication and inventiveness about the production of physical objects. In recent years, we Americans have had every reason to become proud of our sophistication and inventiveness about new engineering developments. Increasingly, however, we recognize that we have barely taken the first few steps towards a high degree of sophistication and inventiveness about people. The target of long-range behavioral science research should be to overcome this deficiency.

Even if behavioral science can promise, at this time, no particular breakthroughs, it can lay the basis for them. And even if they should not be forthcoming, behavioral science can say with confidence that it can repay to its supporters almost any sensible investment of reasonable size in behavioral science research. In the Department of Defense, the FY'61 budget for salaries, allowances, temporary duty travel and permanent changes of station for military and Civil Service personnel, alone, amounts to $18,295,000,000. If one were able to find out and add to this the costs of supplies, training, medical care, barracks and school rooms, of education in private installations, and above all, the costs of the weapons bought for training purposes, one would have a very large budget figure indeed, certainly $20 billion per year and probably half or more of the Defense budget. A saving of 1/365th of the salaries, allowances, and travel, a saving of one day in a year spent at work or play, awake or asleep, would amount to $50 million. Surely such a saving can be produced, surely it can be produced several times over by long-range research. The Department spends less than this on basic research in the behavioral sciences.

To point to potential savings of this order of magnitude, even without predicting particular breakthroughs, is to raise this question:

> How would the products of research in the behavioral sciences be used? What, in other words, are the true needs of the military establishment for research in these fields?

Clearly, the Department of Defense does not need research in these subjects as such. The Department's needs, those which our

sciences can help to meet, are for management sophistication and management inventiveness about people.

Psychology and social science can best help to meet these needs, just as other sciences help to meet other needs, by laying the ground work for a technology, in this case a technology of human behavior. Defense managers of people need to have at hand a technology of human behavior. They need a technology comparable in every possible way to the engineering technology to which weapons managers now appeal when a decision must be made about weapons.

The managers of people in the Department of Defense are:

The commanders and their staffs - at all levels; the men who direct and lead the millions of service men, as well as the reserve forces, the civil servants, and those contractor's technical representatives who work within the military establishment.

The system engineers; the planners of weapon and supporting systems, the engineers who are increasingly coming to recognize that men are components of all systems and that men and equipment must be adjusted rather nicely to one another.

The personnel specialists and the manpower and organization specialists; the managers who must recruit, select, train, and assign men to their jobs in weapon systems, who must arrange military organizations as man-machine weapon systems.

The geo-political policy makers and all those managers who implement their policies and thus have responsibility for the relations between the military establishment and the world outside it; the managers who must work with the State Department and other governmental agencies in determining the policies and relations of the Department of Defense with respect to our own citizens and the peoples of allies, uncommitted, and potential enemy countries.

It is these men whose decisions can be assisted, and improved by a technology of human behavior.

The general problem which managers face is the effect of change on the people of the military establishment. Management under the best of conditions is a high are, dependent on the individual character, the intelligence, and the resourcefulness of the manager. It depends on his ability to use the traditional wisdom and common sense about people that have been accumulating over centuries of military experience. It depends also on the manager's ability to improvise new solutions, as conditions change. When conditions change, there is an inevitable strain on the art of management.

Conditions are changing rapidly today. Each year, conditions change more rapidly. Every step forward in natural science, each advance in engineering technology, changes men's weapons, their vehicles, the organizations in which they work, their relations to people outside their own establishment. Military man's environment is expanding. The general form of the expansion is not the relatively simple geographical one into the arctics, the desert, the tropics, underseas, or even into space. The general form of the expansion of the military man's environment is an expansion into a world of machines and into new social settings. As the world of machines and the social settings change, ever more and more rapidly, the art of management will often be overstrained.

A technology of human behavior may be defined as:

1. Concepts and attitudes about people, -- based on advancing scientific theory.

2. Proven techniques for dealing with people and for getting information about them, -- based on advancing scientific methodology.

3. Tested information about people, available on file, in handbooks, and in the memories of behavioral scientists who serve on the staffs of the Defense managers. Technological information is information based on controlled observation, and is expressed, preferably, in formulae, tables and graphs, that is to say it is not only tested but it is increasingly quantitative as the sciences underlying the technology advance.

A technology of human behavior is necessarily dependent on psychological and social science advance. The production and development of such a technology should be the general objective of Defense research in psychology and the social sciences. When available, this technology should be used by Defense managers and their human factors engineering advisors.

I am under no illusions, I hasten to add, that a technology of human behavior, alone, will itself "solve" any single one of the human problems which military management faces, and will face in ever-increasing number over this decade and the next.

The management of people will remain an art. It will always call for wisdom and common sense, for mature judgment, for seeing many aspects of situations beyond those covered by any conceivable scientific development. No "cookbook" of assorted facts and information, however well established and organized the facts and information may be, can reduce the management of people to a routine function or enable final management decisions about people to be computerized. But the art of management can be helped. It already has been helped by technological developments in psychology and the social sciences. Let me give you a few examples.

In the years before World War I, psychologists developed, from the theory of evolution, the concept that men differ from one

another, with its corollary that men must be treated individually. In World War I, psychologists showed the significance of measured individual differences in military effectiveness. They applied the early single factor theory of intelligence and, later, the more modern multi-factor theory, to the techniques of aptitude testing and the military classification of men. The concept of individual differences, and this application of it, make an enormous difference in the ability of our educational and training managers to support the very high degree of specialization required by operations in a world of machines.

In much the same way, and in the same time period, studies of the reflex arc, of the association of ideas, and the rise of the behavioristic theories in psychology led to the concept of man as a machine and to the techniques of time and motion study. In World War II and since, this concept, when allied with modern laboratory psychology and with interdisciplinary studies in operations research, cybernetics, and information theory, led to the whole field of human engineering and is now helping to develop the concept of man-machine system, a concept which is playing an ever-more important part in modern weapon development.

Fortunately perhaps, in the Western World, the development of the concept of man as machine was paralleled by the development of studies in abnormal psychology, studies which brought out the importance of motivation and morale in the normal, as well as the abnormal, man; studies which led to continuing efforts to assess personalities and to the successes, beginning in World War II, in the measurement of the attitudes of military men.

These examples demonstrate that a technology of human behavior can be developed and that it is helpful to the military manager when developed.

Let me briefly turn next to a more specific question about Defense needs. What are the particular fields of military activity in which a technology of human behavior could be most helpful at the end of the coming decade. If we consider weapon systems now on the drawing boards, if we consider military plans, let us look ahead to the time period when, if the research is successful, the resulting technology would be available to assist military managers. I find four general military topics to which the research should contribute. These are:

1. Weapon systems,
2. Personnel systems,
3. The processing of information and intelligence,
4. The cold war.

For this audience I doubt that I need to expand in a general way on the continuing importance of these topics. You all recognize their significance and the potential contribution of a technology of human behavior to them.

"READY" AREAS

My second major question concerns the readiness of psychology and the social sciences to develop, over a ten-year period, a technology of human behavior relevant to these four, military problem areas. In the last year, I have reviewed the progress of research across the board of the behavioral sciences, particularly the research which might contribute to the development of a useful technology. I have little or no concern with the more or less theoretical question whether such research should be basic or applied. There is some reason to doubt that the issue of basic vs. applied research is relevant to research on human behavior, since much research on human behavior must be conducted in relatively realistic, operational settings, even though these be simulated settings located in laboratories. The most theoretical studies conducted in such settings usually produce products and information which are directly usable. However, my concern is with research programs which would have general usefulness, which would contribute to a generally useful technology, and such research inevitably involves theory. Inevitably it will be long-range research.

In this year, I have explicitly considered upwards of forty possible research programs and many others, of course, received brief attention. Many were discarded because current progress appears to be satisfactory; a new kind of support is unnecessary. Others were discarded because present support of them is appropriate. Still others were discarded because they were too visionary, too unlikely to be successful in the time period under consideration; in these fields the present grant-in-aid approach, backing the occasional genius and the well-designed particular project, is appropriate. My concern is with concentrated programs, long-term programs with a reasonable chance of success.

I find three fields of behavioral science which are now ready to advance and to produce a generally useful technology relevant to Defense needs. For one of these fields, I see three appropriate approaches. The fields themselves are:

1. Human Performance.
2. The Adaptation of Complex Organizations to Changing Demands.
3. Persuasion and Motivation.

Let me discuss each in turn.

The general questions to which research should be addressed in the field of human performance are easy to state -- they are harder to answer. How can the performance of military tasks be improved? What levels of performance can be expected of men of different characteristics and backgrounds under different conditions of work? How can the degradation of performance under

difficult, changing *conditions* be prevented?

The primary concern is with human performance in a world of machines, in a world of ever-increasing automation. Men's functions, their roles, are changing as we enter into a world of machines. In a world of machines, men's brains are steadily growing in importance. In a world of machines, men serve as system components. They tend to serve the functions of:

1. Information Processor.
2. Decision Maker.
3. Team Member.

In a world of machines we need to know all we can know about how men receive information, perceive patterns in information, and code information -- categorizing and structuring it. We need to know all we can know about how men decide to seek more information, decide to reprogram, and decide to use their men and machines in action. We need to know all we can know about how men communicate with their team mates, how men time their work to match one another's, and how men learn enough of the specialities of others to work effectively together.

These are the fields of human performance in which research progress and a technology of human behavior will be most needed and can be approached by 1970-75. Within these fields we need to know all we can know about:

1. Men's engineering characteristics.
2. Men's inventive, or reprogramming characteristics.

Men's engineering characteristics are those characteristics which a system planner must know about when he designs a man-machine system. They are characteristics similar in all respects to the chatacteristics of machine. The system designer has, at hand, an immense amount of information about the standards of performance to be expected of materials and devices. It is this immense amount of information, readily at hand or easily obtainable about materials, that underlies the modern pace of invention of machines. System planners and personnel men need comparable information about people. They need to know, in terms of the same units of measurement as are used to measure machine performance, what levels of performance can be expected of various kinds of men, working under various kinds of background circumstances, on a wide variety of tasks under standardized conditions.

We also need to know all that we can know about men as inventors. I don't necessarily refer here to the great inventive geniuses -- to the Einsteins or even to the Edisons -- although behavioral scientists will know more about men like these too before they are through -- but I refer at present to the lower levels of inventiveness, perhaps better described by the modern term, the reprogrammer, than by the older term, the inventor.

Men have a way of adjusting their work to suit themselves. Sometimes they raise Cain by doing so; by insisting on doing things in their own way, they defeat all the best-laid plans of Commanders and system designers. And yet it is this characteristic which makes men -- men. It is this characteristic which is the best reason for including men as components in our otherwise highly automated systems. It is this characteristic which makes systems grow in effectiveness in spite of unexpected change in the conditions under which the system operates.

Men's engineering characteristics and their reprogramming characteristics need to receive more intensive study than they have yet been given. Long-term study of these aspects of human performance is needed. Three approaches to them are proposed:

1. Men's performance in complex man-machine systems.
2. Men's performance in individual intellectual skills.
3. Men's performance as team members.

In adopting three approaches to the same problems, three fruitful trends in modern psychology would be reinforced: system thinking; individual thinking; and team thinking. In each case the end objective is a broadly useful technology of human performance.

I will not here attempt to spell out in detail the kind of work that is needed under each of these three approaches. A detailed seminar of some hours duration would be needed to cover all three and after dinner is not the appropriate time for this.

The second recommended program concerns complex organizations. The essential problem here, from the point of view of the Department of Defense, is the adaptation of military organizations to changing demands. The Department faces today, and will indefinitely continue to face, an organizational crisis. Defense organizations from the lowest units right up to our three, or four, (sometimes conflicting) Armed Services are necessarily in a continual state of flux, today.

The Defense organization is exposed to changing demands. It faces the technological revolution. Thus, for each new weapon, new problems arise of fitting together the weapon and all the specialized men it requires into a coherent unit and of fitting this new kind of unit into a pre-existing structure. It is no criticism, it is indeed one of the strengths of military organization, to say that it changes slowly in response to technological advance.

The Department also faces a condition of continuous alert. That good friend of behavioral science, Colonel Munson, used to say that the Army no longer retires to its reservations like the Indians between wars, segregating itself from the world at large and waiting to fight a new war in the manner of the last. It must continuously be on the alert for

new kinds of war, started without warning, in any part of the globe.

The military establishment of today and tomorrow must operate through semi-autonomous units, dispersed over the face of the earth, often mobile, often isolated. Regardless of advances in computers and communications, such units must be ready to react intelligently, in accordance with plan, and in accordance with local circumstances which will differ radically from anything anticipated and programmed on the computers before the first blow was struck.

The Department of Defense must coordinate its three Armed Services and it must coordinate their activities with those of our allies. Here, too, changing demands will be the order of the day.

The Department of Defense and our country must face up to the fact that the totalitarian countries seem to be successful in integrating political and military objectives. The Department must somehow help our country to achieve a similar integration, retaining, nevertheless, the free-world principles of civilian control over the military and non-interference in the internal affairs of nations with whom we are at peace.

The basic Defense organization was devised in the days of man-to-man combat. Its key concept is that of many identical or highly similar units at the bottom, pyramiding slowly to a peak at the top. As the technological revolution advances, as the other demands continue, the Defense organization is already adapting. The staff revolution is one sign of adaptation. So, too, is the prevalence and dependence on informal briefings, which bypass all command and staff channels. So, too, is the appearance of many specialized units and of those monsters, the coordinating committees. The Department will continue to adapt. Our question can only be whether research on the principles of organization can assist in the adaptation.

Behavioral scientists hold that research can assist, although in this field their claims are somewhat more modest than for human performance. A broad technology of organization seems more remote than a technology of human performance. This remoteness is not a good reason, however, for further delay in making the fundamental studies needed in order to produce a technology.

Research on organizations to date has been dominated by three kinds of thinking. Until a few years ago, the workers, the employees of organizations, have been conceived as automata, whose own desires and motives are of little importance. A few years back the human relations view came to the fore, emphasizing the importance of each individual and of securing his active participation in pursuit of goals of his organization. Still more recently, the game theorist and the information theorist have dominated the scene, leading to emphasis on decision making and the communication of information, and to a problem solving view of the role of individuals in organizations.

These conflicting theories of organization persist. I believe that the theoretical conflicts will continue to persist, for so long as students of organization are forced to follow the case-study approach. Most of the empirical studies in this field have been of single organizations. The case-study method is valuable but it encourages subjectivism, undue sensitivity to the opinions of the research worker or of the managers who requested the study.

The Department of Defense should support comparative studies of organization, of military organizations primarily but not necessarily of military organizations alone. Objective, empirical comparisons of military and industrial organizations would be very valuable, as would be comparisons of our military units with comparable units of our allies. The units chosen for study should not be picked, however, because they happen to be available, or because their leaders happen to desire a study. They should be chosen deliberately in order to test significant, theoretical points at issue.

The studies should concentrate on these four particular fields, which have special military importance:

1. Organizational Goals.
2. Management Strategies.
3. Incentive Systems.
4. Coordination and Control.

The last of the three areas in which a major research investment is recommended is the area of persuasion and motivation. There has been continuing resistance in this country to an explicit, public recognition that research on this topic, an improved scientific understanding of it, is a necessity. The topic has been rather tenderly dealt with under various euphemisms - the word "propaganda" was succeeded by the word "psychological warfare" and the search for an innocuous-sounding substitute for the word "psychological warfare" continues; such words as "the image of our country" are now popular. At the same time, our leaders are routinely criticized by the country as a whole for failure to anticipate the impact of our weapons, of our national actions, of our geo-political policies on our own service men, our own people, our allies, and others in the world outside.

If there is still serious question about the propriety of the Department's entry into long-range research in this field, I would remind it that, when the news broke that the British Army of our Revolutionary period was hiring German mercenaries, General George Washington wrote President John Hancock of the Continental Congress inquiring whether it might not "be advisable and good policy, to

raise some companies of our Germans to send among (the German mercenaries) when they arrive, for exciting a spirit of disaffection and desertion." Thomas Jefferson included a list of the "crimes" of George III in the Declaration of Independence. -- and Abraham Lincoln carefully timed his release of the Emancipation Proclamation.

We can improve on their techniques, today - but be need to be able to do a great deal better than they did, tomorrow, if only because of the deliberate use of persuasion by others against us.

Persuasion is the term used to describe all those methods of influencing people through means which are short of force, or the threat of force, or direct economic bargaining on the one hand, and which are short of education and training on the other hand. Persuasion operates through relatively permanent changes in the attitudes of men and their motivation. Clearly, changes in attitudes and motivation result indirectly when force or threats or economic methods are used, and in the course of education and training.

Persuasion, then, characterizes the normal, everyday intercourse of people. When people explain their reasons for action, when they discuss a topic, when they argue, much of their intercourse with one another represents a direct appeal to persuasion. Persuasion is not only a kind of weapon in itself, one which reinforces or degrades the effects of the destructive weapons and the effects of economic warfare, but also one which flows from every action one takes. It is high time that our nation takes deliberate steps to try to understand this weapon and to build a technology to aid in its use.

For the free world, the ultimate objective in the study of persuasion and motivation is to build a technology which will be adequate to the task of countering irrational appeals by an appeal to reason. It is my considered opinion that research on:

1. The processes of attitude change,
2. The effects of group memberships on attitude change,
3. The effects of cultural differences on attitude change,
4. The role of persuasion in large-scale social change is now ready, if properly supported, to deliver products which will permit a major step forward in this exciting task.

PRESENT SUPPORT OF BEHAVIORAL SCIENCE RESEARCH

My third major topic is the relation of present support of research in these fields to the support needed to advance most rapidly.

The military departments now support R and D in my three recommended areas, either through their in-service laboratories and the laboratories of their industrial contractors, or through the contracts and grants of the Office of Naval Research, the Air Force Office of Scientific Research, or the Army Technical Services.

The in-service and industrial laboratories are doing an excellent, a top-notch job, within the limits of their primary missions and responsibilities. Their primary job, of course, is the development of specific weapon and supporting equipment, and the primary job of the human factors people within these laboratories is to solve the special human factors problems within such equipment. The human factors laboratories are deeply involved in solving many, highly special problems: problems of acceleration and deceleration, isolation, and weightlessness; problems of detecting and tracking targets displayed on specific kinds of dials or oscilloscopes; problems of communication under particular conditions; and so on. The laboratories also have facilities and funds for more general studies and with these they are making notable contributions to a more general technology of human behavior, and to theoretical development in these fields. These more general facilities and funds are small, however, in relation to the depth of the need in the three fields of present concern.

The military departments also operate research contract and grant programs in these three fields. ONR, AFOSR, and the Army Technical Services ably provide support across the whole broad field of psychology and the social sciences. These agencies have fertilized many areas. It is the result of such fertilization, by these and other government agencies, such as the National Science Foundation, and by the private foundations, that has made it possible to say that three fields are ready for intensive development.

The current method of support by these agencies is to back men and limited, well-designed projects. These agencies provide to many separate men with ideas relatively small sums, on an annual or at least on a relatively short-term basis. This is a time-tested and proven method of producing advance in the uncertain world of research. Behavioral science, generally, benefits from this method. I hope that the method will be continued and extended.

THE KIND OF SUPPORT NEEDED

There is a question, however, whether attention to special topics in the in-service laboratories, and backing many separate scientists across this whole broad field, is enough. Particularly, there is a question for our three areas which are so important for the Defense Department as a whole and which are ready for long-term, concentrated support.

Let me refer again to the field of aptitude testing. A condensed history of the state of the art of this topic may be informative (figure 1). The state of the art of aptitude testing took a just perceptible step forward more than a century ago when the astronomers, about 1820, recognized the personal equation. The real advance was stimulated, however, by Darwin in his Origin of Species with its emphasis on variation between animals. From the variation in physical characteristics observed by Darwin, it was only a short step to variation in the far more important, mental characteristics. This step

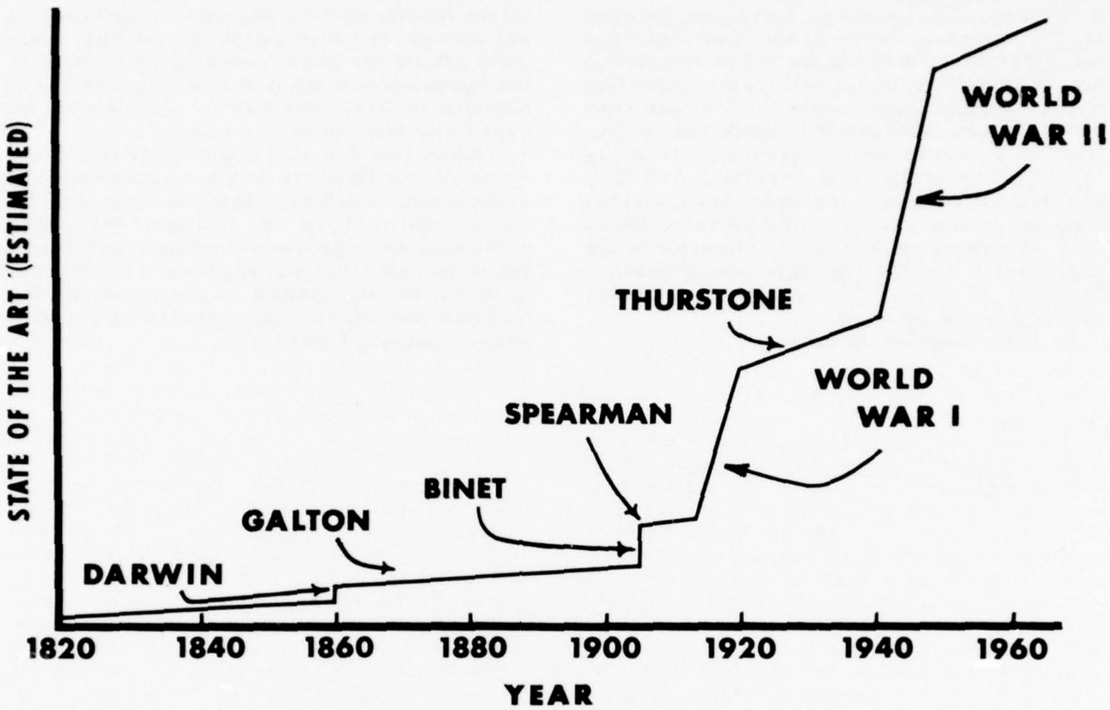

Figure 1. Development of the State of the Art of Aptitude Testing for Military Use

was taken by Francis Galton in his 1869 book on Hereditary Genius, his 1883 book on Inquiries into Human Faculty and Its Development, in which the idea of a mental test was born, and in his Anthropometric Laboratory established at the South Kensington Museum in London in 1884.

The basis for modern development was laid by Binet in France in 1905, with new concepts for the measurement of complex abilities. At about the same time, Spearman, in London, developed the general factor theory of intelligence, expanded to a multi-factor theory, and applied to aptitude testing, chiefly under the influence of Thurstone during the 1930's in this country. These are a few of the individuals to whom a wide-awake Office of Naval Research, an Air Force Office of Scientific Research, or the Personnel Research Branch of the Army's Adjutant General might best have made fertilizing contributions, if these agencies had been operating in England, France, and this country at the times stated.

The greatest advances in the state of the art, however, were taken in World Wars I and II. On each of these occasions, relatively large numbers of scientists concentrated their attention on a topic "ready" for technological advance. The best possible conditions for technologically-oriented research in this subject obtained. There were available, for the first time, large numbers of subjects from many walks of life and an adequate number of technical assistants for the key scientists concerned. The result was a tremendous technological development, one of great, continuing usefulness for the Department of Defense and the nation, today and tomorrow, a development which put the United States far ahead of all other nations in this field. Relatively large and suitable resources were made available to a field ready for concentrated, technological development.

I believe that the three areas mentioned above are ready for this kind of development today. The key scientists are trained and available. The exploratory work is relatively advanced, much of it subsidized by the Department of Defense. The research methods are ready for use, ready to produce a

relatively great advance in the state of the art, in the technology of human performance, complex organization, and persuasion and motivation.

THE SUPPORT NEEDED

I believe that we need continuous, stable, long-range support for the three areas I have mentioned. For human performance, the need is for several, large-scale, well-equipped laboratories to develop the art of simulation and to apply it systematically to the controlled observation of large numbers of human subjects. These laboratories should not be distracted, as our in-service laboratories are by the need to apply their results. And they obviously need more, and longer term support than our normal grants-in-aid provide. Three such laboratories are needed to explore the engineering and the reprogramming characteristics of man. These are laboratories oriented to the study of:

1. Man-Machine Systems.
2. Human Intellectual Skills.
3. Team Performance.

I believe that we also need a small, but stable, Institute of Organization Research aimed at the empirical, theoretical, and comparative study of organizations, military organizations primarily but not exclusively.

I believe that we need to supplement our fairly active applied research programs on persuasion and motivation by making long-term grants for basic research to several of the agencies at work in this field. The combination of basic and applied work should be especially fruitful in this case.

I thank you for this opportunity to expose some of my thoughts to your comments and criticisms. I am sure that no topic can be more important for the military establishment than an improved scientific understanding of human behavior, expressed in the form of a technology suited to the needs of the Defense managers whose decisions concern people. Again, I thank you.

CHAPTER 11

U. S. ARMY HUMAN FACTORS ENGINEERING COMMITTEE PRESENTATIONS

A. COMMENTS ON THE HUMAN FACTORS ENGINEERING COURSES AT McGILL And The UNIVERSITY OF MICHIGAN: Lt Col Harold A. Tidmarsh, TC, Deputy Director of Research, U.S. Army Transportation Research and Engineering Command, Ft. Eustis, Va.

B. CONFERENCE HIGHLIGHTS AND AHFEC ANNUAL SUMMARY: Dr. Lynn E. Baker, Army Research Office, Office of the Chief of Research and Development, Washington, D. C.

A. COMMENTS ON THE HUMAN FACTORS ENGINEERING COURSES AT McGILL AND THE UNIVERSITY OF MICHIGAN by Lt Col Harold A. Tidmarsh, TC, Deputy Director of Research, U. S. Army Transportation Research and Engineering Command, Ft. Eustis, Va.

[Ed. note: The U.S. Army Human Factors Engineering Committee (AHFEC) acts as a co-ordinating agency for the Chief of Research and Development in the allocation among the U.S. Army Technical Services and USCONARC of quotas for attendance of selected military personnel at short orientation courses in human factors engineering. The purpose of these and similar efforts of the AHFEC is to acquaint Army Personnel concerned with equipment design with the nature of human factors engineering problems and practices, and with how such problems may be recognized and solutions sought.

At the Fifth Annual Army Human Factors Engineering Conference, held at Redstone Arsenal on 21-24 September 1959, the AHFEC presented comments from two officers who had attended the course at McGill from 9 through 19 September 1959. These reports suggested certain modifications which might be desirable, and strongly recommended continued participation by Army personnel in such courses.

In June and July 1960, being apprised of a similar course to be conducted at the University of Michigan, the AHFEC recommended: that both the McGill and Michigan courses be utilized as resources for the above stated orientation training purposes; and that one officer attend both courses for the purpose of providing this Conference and the AHFEC some suggestive comparative evaluation and guidance for future planning. Col Tidmarsh was selected for this task, and his comments are presented herewith as well deserving the attention and consideration of all concerned.

--L.E.B., Gen. Conf. Chmn.]

PURPOSE

The purpose of this paper is to present comments regarding the short courses in human factors engineering (HFE) offered by the University of Michigan and by McGill University during the summer of 1960, and to submit a comparison of the two courses.

SCOPE

This paper is limited in scope because the writer is an engineer with little training or education in psychology.

GENERAL COMMENTS

a. The course at each university was sponsored by the Department of Psychology; hence the approach to man-machine systems was from the point of view of the psychologist, with less attention given to the engineer's viewpoint.

b. Both courses were somewhat theoretical, requiring some basic knowledge of psychology for complete understanding and assimilation. The principal difficulty was concerned with communication. The language of psychology is not the same as the language of engineering, and most of the students in each course were engineers. Neither course provided a glossary of terms, nor did most of the instructors or speakers completely define the terms they used. In general the McGill course was much less theoretical and much more practical from the engineer's viewpoint than the Michigan course.

OBJECTIVES OF THE COURSES

a. Michigan - From the man-machine systems viewpoint, to clarify the objectives and present the general concepts and theoretical formulations that can provide guidelines for the solution of practical problems.

b. McGill - To introduce professional engineers to the literature and techniques of good human engineering, in order to assist in the design of equipment so that (1) the operator and maintainer can work with maximum efficiency, and (2) more individuals can be trained more quickly to operate or maintain the equipment.

ATTENDANCE

a. Michigan - 67 Students	
U. S. Army	17
U. S. Navy	1
U. S. Air Force	17
U. S. Industry	27
U. S. Government	4
U. S. Education	1
b. McGill - 18 Students	
U. S. Army	12
U. S. Industry	1
Canadian Army	1
Canadian Navy	3
Canadian Industry	1

INSTRUCTION

a. Michigan

(1) Used a total of 16 instructors and guest speakers during an eleven day course. Of this number, 9 were from the Department of Psychology and the remaining 7 may be described as practicing psychologists.

(2) Course was presented in a somewhat formal manner in a large lecture hall. Because of the large number of students, active participation was difficult. The instructor-student relationship was never quite eliminated. Some use was made of visual instructional aids.

(3) Each afternoon the class was divided into small groups with an instructor, and a one and one-half seminar was conducted.

b. McGill

(1) Used a total of 6 instructors and guest speakers during a ten day course. Except for one, all of these could be described as practicing psychologists. The exception was from the Michigan Department of Psychology; he presented the same lectures in both courses. No instructors from the McGill Department of Psychology took active part in the course.

(2) Course was presented in an informal, round-table-discussion, seminar manner. Because of the small number of students, active participation was easy, in fact the students got to know each other and the course leader rather well. After a few days the instructor-student relationship practically disappeared. Extensive use was made of visual and other instructional aids.

MATERIAL COVERED

a. See Annex A for Michigan.

b. See Annex B for McGill.

c. The material covered in each course was much the same in many instances, however, the approach to the material was different. The Michigan course approach was largely theoretical, with quite a bit of theoretical and laboratory experimental data being presented. The McGill course was oriented to deal more with practical matters rather than theoretical issues; the primary objective being to develop a point of view, not to pass on specific data.

CONCLUSIONS

a. Both courses were adequate and successful in presenting the problems which are inherent or are created in the design and development of man-machine systems.

b. The provision of guidelines to the solution of these problems was undertaken from the more theoretical psychological aspect by Michigan, and from the more practical psychological aspect by McGill.

c. Even though the accepted North American description of a human engineer is "an engineer with some psycho-physiological training" neither course made use of or even produced such a person.

d. Both courses would have benefited by being oriented, to a greater degree, toward the engineer's viewpoint.

e. A glossary of terms should be provided each student.

f. The scope of both courses was somewhat broad and in some instances somewhat intensive. At times students appeared to become lost in detail, this was especially true of the Michigan course. It might be more advantageous to deal with specific human engineering problems the engineer is called on to consider or solve. In a course of 10 or 11 days duration everything cannot be covered. Perhaps an introduction to the general problems and a discussion of some of the more essential specific ones with definite guidelines as to their practical solution would be more beneficial.

g. The problems of HFE are directly related to the Army's problems in the design and procurement of man-machine systems and in the training for and operation and maintenance of these systems. Therefore, even though there is room for improvement in both these courses, they are both of benefit to Army personnel who are involved in designing, procuring, operating and maintaining man-machine systems.

h. In my present duties both courses are of value. This value could have been enhanced had the courses been oriented more toward engineering.

i. Because the McGill course was more practical, had fewer students, and was conducted in a much less formal atmosphere, I received greater benefit from it than from the Michigan course.

RECOMMENDATIONS

a. That training in the field of HFE be continued for selected Army Personnel (both military and civilian).

b. That attendance at short courses of the nature of those presented by Michigan and McGill be continued in order to orient a maximum number of Army personnel to the problems of HFE. Perhaps educational institutions could be encouraged to design their courses specifically to meet the Army's needs.

c. That selected Army personnel receive longer training and education in HFE so as to produce individuals who are professional human engineers and who fit the accepted description of a human engineer i.e., "an engineer with some psycho-physiological training."

d. That consideration be given to incorporating a HFE short orientation course into the Army's School system, at the outset this might be done in the Technical Service Schools.

e. That consideration be given to establishing a MOS for both officers and enlisted men in the field of HFE, and an occupational code for Civil Service Employees.

2 Annexes:
A - Michigan Course Titles
B - McGill Course Titles

ANNEX A

TO COMMENTS ON HFE COURSES

University of Michigan
Human Engineering Concepts and Theory
Titles of Presentations 1960

1. 13 June - *Introduction
   *History, Scope and Objectives of Human Factors Engineering (HFE)
   System Simulation
   Mathematical Model of Human Performance

2. 14 June - *Implications of the System Concept
   Human Memory
   *Automated Training Devices
   Adaptive System Models

3. 15 June - *Functions of Men in Systems
   Automation and the Worker
   Analog Computers in Simulation of Man-Machine Systems

4. 16 June - *Identification of Critical HFE Problems
   *Tracking and Skill Performance
   *Perceptual Learning
   Signal Detection Theory

5. 17 June - *Human Information Handling Signal Detection Theory
   *Derivation of Transfer Functions, Psychological Measurement and a Theory of Data

6. 18 June - Visit to University Department of Psychology Laboratories

7. 20 June - *Coding and Display of Information
   *Activity Data Gathering Techniques
   *Human Decision Making

8. 21 June - *Coding and Display of Information
   *Design for Ease of Maintenance
   Consumer Acceptance Research
   *Human Decision Making

9. 22 June - Roles for Men in Future Systems
   *Reducing the Deleterious Effects of Stress
   HFE Problems in Manned Space Vehicles
   HFE Aspects of Operation and Maintenance of Space Systems

10. 23 June - HFE Research on Telephone System
    *Integration of HFE Contributions in System Development Cycles
    Field Testing of Man-Machine Systems

11. 24 June - Novel Display Methods
    *Design Engineer's Use of HFE Data
    *New Horizons for HFE

*Some duplication in McGill Course

ANNEX B

TO COMMENTS ON HFE COURSES

McGill University Short Course
Human Engineering
Titles of Presentations 1960

1. 7 September - *Introduction
*Fields of Psychology
*Principles of Learning and the Acquisition of Skills
*Breakdown of Skills (fatigue)
*Training for Human Engineers

2. 8 September - Vision
Illumination
Legibility
Visual Warning Systems

3. 9 September - Hearing and Bio-Acoustics

4. 10 September - *Visual Display of Information

5. 12 September - *System Design
*Transfer Functions
*Man in the Control Loop

6. 13 September - Manual Controls
*Tracking Performance and Behavior
Human Control Forces
Design for Optimum Control
Human Monitoring (Vigilance)
*Performance Decrement and Avoidance

7. 14 September - *Man as an Information Handling System
Operational Research

8. 15 September - *Design for Ease of Maintenance
Planning a Maintenance System
Layout of Workspace

9. 16 September - *Decision Making

10. 17 September - *Human Engineering a System
Summary

*Some duplication in the Michigan Course.

B. CONFERENCE HIGHLIGHTS AND AHFEC ANNUAL SUMMARY, by Dr. Lynn E. Baker, Army Research Office, Office of the Chief of Research and Development, Washington, D. C.

ARMY, INDUSTRY AND THE SOLDIER

As your General Chairman and the Chairman of the Army Human Factors Engineering Committee (AHFEC) I am each year privileged to report to you on major results of the work of AHFEC during the preceding year, and to attempt a summary evaluation of the Conference as its final act. This is an altogether pleasant assignment because each year I have been able to report my sincere view that this Conference has been even better than its predecessors. Lest this give offense to our hosts of former years let me hasten to add that this is in large measure due to the fact that each Conference has built on those which preceded it. Each Conference has furnished a record of progress in part attributable to its predecessors.

For example, consider the very theme of this Conference, "Army, Industry and the Soldier," so ably expressed by our keynote speaker, Mr. Richard S. Morse, U.S. Army Director of Research and Development. This theme was selected by the AHFEC in response to the comment of General Trudeau at your last Conference that industry should have increased representation and participation in these programs. In consequence of this guidance, no less than a half-dozen of the best papers on this excellent program were contributed by representatives of industrial and other contract facilities who, I am sure, are proud to consider themselves full participating members of the Army R&D team. We are thus assured that industry and the scientific community at large, as well as the Army, are becoming increasingly aware of the necessity for proper consideration of human factors in the design of Army materiel.

HFE AND THE TOTAL ARMY HUMAN FACTORS R&D PROGRAM

As a further example of the increased stature of our Conference this year, consider that last year (again by General Trudeau's guidance) you first publicly asked yourselves the question: "What is our proper relation to the rest of the Army's human factors R&D program?" The excellent papers presented at this Conference by representatives of HumRRO, PRB and NTDC give evidence that we must and can find a satisfactory answer to this question. Certainly it is abundantly clear that you cannot properly conduct your human factors engineering research and development without full and effective exchange of information with these important agencies. Nor can they exploit their opportunities to the full on the Army's behalf without complete information on your human factors engineering programs and results.

These facts, and their vital importance to USCONARC as the "user" of Army materiel, have been carefully documented and weighed during the past year by a working group of the Army Scientific Advisory Panel (ASAP) under the chairmanship of Dr. Roger Russell of Indiana University. Many of you have met with and assisted this distinguished group, which also includes: Dr. William Kappauf of the University of Illinois; Dr. E. J. McCormick of Purdue; and Dr. Delos Wickens of Ohio State University. The recommendations of the so-called "Russell Report No. 1" are now being considered for action by the AHFEC, USCONARC and the Army General Staff.

The "Russell Report" comes at a particularly opportune moment, for it coincides with and complements an independently reached conclusion of the Roderick Board: that increased emphasis must be placed on human factors from the very beginnings of the design of Army materiel. This Roderick Board finding has been approved, and its implementation directed, by the Secretary of the Army.

PREDICTIONS

On the basis of the above conference highlights and related activities of ASAP, AHFEC and the Army General Staff I feel that I can predict the following developments affecting Army HFE in the future:

a. In general, there will be increased concern at USCONARC with improved human factors engineering throughout the design cycle--from the originating of Qualitative Military Requirements (QMR's) right through to engineer and user test.

b. More specifically, Captain Hawkes's fine series of studies, reported in full (tho summarized) form at this Conference, could well furnish a substantial basis for a new QMR for communications equipment development.

c. Most specifically of all, upon the invitation of the Chief Signal Officer, the Seventh Annual Army Human Factors Engineering Conference will be held on 3-6 October 1961 at the University of Michigan, Ann Arbor, Michigan.

ACKNOWLEDGEMENTS

This Sixth Annual Army Human Factors Engineering Conference has been orders of magnitude better than were the five preceding conferences in this outstanding series, and for this I wholeheartedly commend all who participated in its discussions.

We well know that these stimulating exchanges of information could not have been so fruitful and effective without the superb setting which was provided here by Major General Wilson, Commanding General of the U.S. Army Engineer Center at Fort Belvoir, by Brigadier General Jewett, whose school facilities we enjoyed, and by Colonel Walker's Engineer Research and Development Laboratories.

This Conference desires specifically to record its appreciation to those who, under such leadership, worked so devotedly behind the scenes for our convenience and comfort:

To Mr. Jacob Barber and Major Perry Tate, who "sparkplugged" the entire effort;

To Mr. Davis and Miss Morrissey, of the ERDL Technical Liaison Office, who handled the many problems of public information and press coverage of the Conference;

To Lt Colonel Birra, who not only arranged our luncheons and social affairs, but even provided coffee in the Demonstration Area;

To Captain L. B. Mahan, Operations Officer here at Humphrey Hall;

To M/Sgt J. E. Healey, Building Custodian, and Film and Sound Technicians SP/6 Bennie Powell, Sgt C. C. Lee and Mr. C. A. MacGregory; to M/Sgts Stoltenberg, Hanlen and Dolozik who handled the microphones and generally facilitated the notably smooth running of the conference work; and to Miss Mary Ingham who so cheerfully coped with all administrative details.

To those and to the many, many others who handled registration, billeting, transportation, and the fine demonstration, we give a rousing standing vote of thanks as we now adjourn the Sixth Annual Army Human Factors Engineering Conference.

ADJOURNMENT

The Conference adjourned at 1545 hours on 6 October 1960.

APPENDICES

I. Roster of Conferees

II. Current Work Programs, Bibliographies and Biographical Directories of Professional Personnel of U.S. Army Technical Services Human Factors Engineering Activities:

1. U.S. Army Chemical Corps

2. U.S. Army Corps of Engineers

3. U. S. Medical Service

4. U.S. Army Ordnance Corps

5. U.S. Army Quartermaster Corps

6. U.S. Army Signal Corps

7. U.S. Army Transportation Corps

APPENDIX I
ROSTER OF CONFEREES

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2. Mr. Marshall D. Aiken
Signal Research Office
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3. Mr. Robert G. Alexander
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4. Mr. C. W. Anderson, Jr.
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11. Mr. Earl W. Barr
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12. Dr. Norman Barr
General Motors Corp
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13. Lt Col George J. Bayerle, Jr.
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14. Mr. R. W. Beal
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15. Col H. C. Besancon
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16. Lt Col A. F. Birra
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18. Mr. Edward W. Bishop
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19. Mr. Abbott Blank
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21. Mr. John F. Bodenburg
US Naval Training Device Center
Port Washington, N. Y.

22. Capt Philip L. Bolté
US Army Armor Board
Ft Knox, Ky.

23. Lt Col Lawrence W. Brady
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24. Dr. Charles W. Bray
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25. Mr. Charles F. Brewer
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32. Lt Col Robert B. Burlin
Nuclear Power Field Office
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33. Mr. Raymond Cahill
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APPENDIX II

CURRENT WORK PROGRAMS, BIBLIOGRAPHIES AND BIOGRAPHICAL DIRECTORIES OF PROFESSIONAL PERSONNEL OF THE U. S. ARMY TECHNICAL SERVICES HUMAN FACTORS ENGINEERING ACTIVITIES.

1. U. S. ARMY CHEMICAL CORPS

U. S. ARMY CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES, ARMY CHEMICAL CENTER, MARYLAND

A. CURRENT WORK PROGRAM

1. Program includes the continual review of all items of Chemical Corps equipment during the period that these items are being conceived, designed, and developed. This review concerns the design and recommended method of operation of this equipment from the viewpoint of human use. In general this type of review includes one or more of three approaches. The first approach is a laboratory test which typically involves simulated use of an item. The second is a field test, usually performed when an item is in an advanced stage of development. The third is the provision of consulting or "application of known principles" service to equipment designers. Application of results of these efforts is in terms of 1. implementation of recommended design changes, 2. revision of written instructions, 3. modification of method of use of an item.

Project	Experimenters	Date Started	Estimated Completion
a. E41-Point Source Alarm	Dr. Earl Davy Mr. Robert Clovis	March 1959	Continuing

The E41 Model Point Source Alarm is currently being developed to replace the standard E-21 Model. The E21 is capable of automatic operation for a period of twenty-four hours. It is necessary, however, that a relatively complex series of tasks be performed in the field in order to prepare this alarm for automatic operation. Design, written instructions, and operating procedures have been evaluated and modified as a result of a series of laboratory tests. A second series of tests will include field use of the alarm system.

b. Field Decontamination Kit	Dr. Earl Davy	Nov 1958	Continuing

A kit has been developed for the purpose of personal decontamination in the field by persons exposed to lethal chemical agents. This kit is being evaluated in terms of time required to learn to use it, actual use time, adequacy of printed instructions, and special difficulties related to its use.

c. M-15 Rocket Propellent Gas Mask	Dr. Earl Davy	July 1959	Jan 1961

Tests are being undertaken on this mask to determine its compatibility with Quartermaster Corps protective clothing when worn by human subjects during exercise.

2. Effects of Military Chemicals on Operational Tasks

A self-rating scale, the Clyde Mood Scale is being used to determine the subjective responses of subjects following the administration of selected incapacitating agents. To date we have demonstrated differences of drug and non-drug conditions in the instance of two centrally acting incapacitating compounds and we have differentiated these compounds in terms of results of administration of the Clyde Scale. A pilot vigilance study recently completed suggests the possibility of chemically augmenting and diminishing performance level on a vigilance task. A series of compounds (candidate CW agents) are routinely screened in human subjects using standard motor, sensory, ideational, and personality tests. Field tests of the effects of these compounds upon persons performing complex military tasks are being conducted. An operant laboratory has been set up for the purpose of investigating drug effects on the behavior of lower animals. Future plans include the investigation of the use of hypothalamic stimulation in controlling the behavior of lower animals employed to detect the presence of CW agents, and the determination of the effects of incapacitating agents upon visual scanning behavior.

2. U. S. ARMY CORPS OF ENGINEERS

U. S. ARMY RESEARCH AND DEVELOPMENT LABORATORIES, FORT BELVOIR, VIRGINIA

A. CURRENT WORK PROGRAM

1. Equipment Evaluation

Title	Experimenter	Date Started	Estimated Completion
a. All-Purpose Ballastable Crawler Tractor	W.H. Leathers	June 1960	Jan 1962

In connection with the refinement and fabrication of 2nd generation tractor the contractor is to make human engineering studies in connection with the operation and maintenance of the unit and safety characteristics.

b. Boilers	W.J. Royall	Continuing	

Safety accessories of improved design are incorporated to decrease safety hazards.

c. Close Order Binoculars	H.G. Johnson	June 1958	July 1961

Performance of the operator under conditions of displacement of apparent eye point from true eye point for binocular operation is being evaluated. Comfort, weight and balance factors for the wearer during prolonged use under various field conditions are being studied.

d. Cranes	T. Freeble	Continuing	

Designs of cabs are studied for increased comfort. Reduction of operator fatigue is being investigated thru (1) type, location and adjustment of seat, (2) type, location of and pressure required for operation of controls, and (3) improvement in size and type of windows in cab and reduction of glare. Ease of maintenance is stressed thru increased scope of maintenance, less man hours required, and decrease of safety hazards.

e. Evaluation of crawler and rubber tired tractors	J.R. Bryant	Aug 1959	June 1961

As part of the overall project, man machine relationships are being studied to determine pertinent factors for inclusion in future specification revisions.

f. Exchange Unit Mobile, 3000 GPH	J.L. Barber	Oct 1959	1962

An evaluation of the man-machine relationships will be conducted in conjunction with the engineering tests of the second prototype of this item of water purification equipment.

g. IR-Visible Tank Mounted Xenon Searchlight	C.D. Charlton	May 1959	Dec 1960

Maintenance and module replacement are stressed in the design for high reliability and reduced downtime. Controls internal to the tank are designed for minimal error when operated without the aid of vision. The mechanism for mounting and locking the light to the tank is designed for rapid operation without the use of tools.

h. Mobile Lithographic Copying Camera	W.H. Holmberg	July 1960	Nov 1960

Design features involving human factors criteria are being checked in conjunction with the production review of the item.

i. Rough Terrain Crane, 20-Ton	J.K. Knaell	July 1960	Dec 1961

Studies will be made and crane will be modified to enhance safety and maintenance characteristics. Engineering tests will determine whether or not safety and maintenance characteristics have been improved.

j. Sawmills	W.M. Royall	------	Nov 1960

Increased safety precautions are incorporated to decrease safety hazards.

k. Universal Scraper Hitch for 18 cu yd, 2 and 4 wheel towed scrapers	J.R. Bryant	June 1960	Nov 1960

The item is being evaluated and modified to simplify design and reduce manpower requirements.

l. Winterized Construction Equipment	Herbert T. Harboe	Dec 1959	Oct 1960

Ease of operation and ease of maintenance on 4 items of winterized equipment (3 tractors and a road grader) are being evaluated with primary emphasis being given to operation and maintenance of the equipment by personnel encumbered by arctic clothing. Results of this evaluation will be applied to future specifications for winterized equipment.

2. Supporting Research -- none.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE PREVIOUS ANNUAL CONFERENCE --NONE

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

Barber, Jacob L., Jr., Human Factors Engineering Coordinator, B.S.-1946, M.A.-1948; Engineering Psychology.

Christian, John F., B.S.-1950, Fire Protection and Industrial Design.

Harboe, Herbert T., Human Factors Engineering Specialist, B.S.-1937, Electrical Engineering.

Holmberg, William H., Project Engineer, B.S.-1956; General Engineering.

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U. S. ARMY ENGINEER GEODESY, INTELLIGENCE, AND MAPPING RESEARCH AND DEVELOPMENT AGENCY, FORT BELVOIR, VIRGINIA

A. CURRENT WORK PROGRAM

1. Equipment Evaluation

Title	Experimenter	Date Started	Estimated Completion
a. Automatic Mosaicker	A. Anson	March 1960	Nov 1960

An intensive effort was made to ensure that the type of controls to be used in the instrument console, the control layout, intensity of illumination of dials and accessibility of controls would allow maximum ease of operation.

b. Diapositive Processing	R.E. Cotten	June 1960	Dec 1960

Man-machine relationships were evaluated to determine the compatibility of human capacity to machine capacity. Study of accessibility and proper location of control valves and levers is being conducted in conjunction with the Service Test. Ease of Maintenance Reviews have indicated deficiencies in accessibility of replaceable parts.

2. Supporting Research -- none.

B. <u>BIBLIOGRAPHY OF PUBLICATIONS SINCE PREVIOUS ANNUAL CONFERENCE -- NONE.</u>

C. <u>BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL</u>

Presser, Sidney, Human Factors Engineer - B.S.E.-1935; M.C.E.-1937; Civil Engineering.

Cotten, Ronald E., Human Factors Engineering Project Experimenter, BSCE-1959; Civil Engineering.

Anson, Abraham, Human Factors Engineering Experimenter.

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3. U. S. ARMY MEDICAL SERVICE

CURRENT WORK PROGRAMS AND BIBLIOGRAPHIES IN PSYCHOPHYSIOLOGICAL STUDIES

A. CURRENT WORK PROGRAM

U.S. Army Medical Research & Development Command, OTSG, Washington 25, D.C.

1. Investigation of Sound and Hearing in Relation to Performance

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

Project	Experimenters	Date Started	Estimated Completion
a. Studies of Audition	M. Loeb A. Jewett	Aug 1954	Continuing

Some work continued in determining the protective effect of the acoustic reflex in the presence of impulsive noises. USAMRL Report No. 396 shows that activation of the acoustic reflex in the presence of machine gun firing noise gives protection averaging 10 db for frequencies of 1000 cycles or higher. A comparison of the attenuation of noise provided by the V-51R earplug and the acoustic reflex is described in USAMRL Report No. 397 and shows that the attenuations are roughly comparable. Two studies, USAMRL Report No. 404 and 409, indicate that the attenuation provided by the acoustic reflex is great for loud sounds and very small for faint sounds.

During the year, studies of animals began, aimed at determining the relation of frequency, intensity, and other noise properties to temporary and permanent auditory damage. This work continues.

A study on the monitoring of auditory signals continued through the year. It was found that reactions to auditory signals were slowed as a function of time on task, but that feedback of information, whether true or false, reduced errors and decreased response time.

External -

b. Effects of Over-stimulation and internal factors on the function of the inner ear	M. Lawrence Michigan	May 1955	June 1961

Two cases of reversible deafness associated with hypothyroidism were studied. Histological studies on hypothyroid chicks showed a region of edema below the sensory cells and above the supporting cells in the acoustic papilla.

An extensive study of the inner ear of a woman who died of other causes after suffering from Meniere's syndrome was made. There was evidence that the ductus-cochlearis had been overdistended by an excess of endolymph and that its rupture had been followed by partial repair.

The effect of middle ear surgery upon the response of the inner ear was reviewed.

c. Measurement of Noise of U.S. Army Weapons	K.D. Kryter Cambridge, Mass.	July 1958	July 1961

A brief description of the various characteristics of impulse noise that may contribute to hearing defects was made. Methods of creating impulse-type noise (simulated gun blasts) that provide independent control of rise time, duration and peak level were outlined. Preliminary attempts have been made to plan and develop a flexible impulse noise generator.

d. Effects of practice on sensory discrimination	R. Bixler - M. Loeb, Louisville	Aug 1959	July 1961

A sound deadened chamber was constructed. Subjects have tracked given frequencies in quiet and in white noise under different incentive conditions. Data are being analyzed to determine whether subjects can discriminate between low frequency physiological noise and low frequency signals.

Project	Experimenters	Date Started	Estimated Completion
e. Localization of sound in depth	I. Hirsh - J.L. Fletcher, St. Louis, Mo.	Jan 1960	Dec 1960

No data reported yet. Study was initiated too recently.

2. Vision and Perception in Relation to Performance

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

a. Studies of Visual Function	G. Harker W. Gogel R. Bailey E. Wist	March 1956	Continuing

Considerable work has been accomplished during the year in evaluating the contribution of cyclorotation of the eyes to the perception of a slope which is in the straight line of sight. Among the difficulties in pursuing this line of investigation was the probability that measures used in the past have unknowingly included an element of perceptual error in addition to actually measuring cyclorotation. Work here has been aimed at clarifying or identifying this perceptual factor and good progress has been made (USAMRL Report No. 419).

Library research has been completed pursuant to looking into the effects of ultraviolet and ionizing radiation upon dark adaptation, with the dark adaptation considered as a possible indicator of exposure to electro-magnetic radiation outside the visible spectrum.

Work on visual perception continues, with this year bringing further development of the interdependent roles, in vision, of retinal disparity cues, convergence function, and accommodative function. Research is beginning again on the problem of relating familiar size of objects to perceived depth, with the aim of further integrating these cues in a single theoretical formulation.

External -

b. Psychophysiology of perception	D.B. Lindsley UCLA	Sep 1956	Aug 1961

Studies have continued on the perceptual blanking phenomenon. Materials readily perceived after brief exposure (10msec) are not perceived if the first informational flash is followed by a second more intense non-informational flash of brief duration (10-25 msec). There is no interference or blank out if the interval is 45 msec or over. The temporal aspects of visual perception are further studied by coupling these limits of interference with the latencies of evoked potentials from the visual area of the brain in human subjects.

c. Perceptual and Physiological Aspects of Uniform Visual Stimulation	W. Cohen	June 1957	June 1961

No data have been accumulated this year while principal investigator has been on leave of absence. Studies will resume in the fall of 1960!

d. Fluctuations in Night Visual Acuity	E.P. Johnson Colby	June 1957	Aug 1960

Data have been statistically analyzed preparatory to final report expected about October 1960.

e. Spectral Sensitivities of Intra-retinal Potentials	L. Riggs Brown	July 1958	Aug 1960

Two types of response functions in small retinal areas have been identified. Using the "stopped-image" technique, spectral sensitivity curves were obtained for isolated areas of the retina. Differences in the sensitivity curves were too small for adequate interpretation. Further experimentation indicated receptors for particular wave-lengths, and matching experiments are planned to follow up these findings for clarification.

Project	Experimenters	Date Started	Estimated Completion
f. Spectral Sensitivities for Small Retinal Areas	J. Krauskopf Rutgers	Sep 1960	Aug 1961

This study has just been initiated and will be a further extension of the terminating study under Riggs.

3. Improvement of Control and Coordination in Performance

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

a. Psychomotor Studies	M. Herbert L. Caldwell W. Evans	July 1956	Continuing

The driver fatigue studies have been under way during the year. Two large scale field operations of three months and six weeks, respectively, involving over 400 men, have been completed, and preparations are in progress for a summer study. The vast amount of data accumulated has been organized and sent to the computer but has not yet been processed. Considerable progress has been made this year, in both methodology, and in actual research.

In biomechanics, a completed study (USAMRL Report No. 411) continued the work on the effects of various body leverage combinations on force output of the hand and arm. This study determined, in terms which are generalizeable, the effect of hand control position on force output of the hand. It was found that the most important single factor was distance of the control from the body. More recently begun studies are carrying this work into a consideration of the factors influencing sustained, rather than peak, output, thus bringing fatigue into prime emphasis. Work in this area will include the effects of drugs on sustained output.

Other recently begun work aims at assaying drug and biomechanical factors in certain motor tasks, primarily in animals at this stage.

External -

b. Certain Physiological Correlates of Psychomotor Functioning	R.B. Malmo McGill	June 1955	July 1961

Experiments were conducted exploring the relations between the variables of task complexity, performance level and activation level. Preliminary analysis indicated that while increasing the task complexity by division of set (instructing the subject to be ready to shift from single to double tracking) may reduce performance level without producing any change in activation, actually increasing the task difficulty (by actually shifting the subject from single to double tracking) may produce a significant rise in activation level. First draft of a paper dealing with all the sleep-deprivation findings is in preparation.

c. Retention of Tracking Skills	A.W. Melton Michigan	Jan 1959	June 1961

Attempts to make the BETA function properly have been unsuccessful. An alternative electronic tracking equipment is being obtained. Pending empirical studies, a literature search on the retention of tracking skills and related perceptual-motor skills has been conducted. An integrative review of previous research is in preparation.

4. Motivation and Balance in Relation to Performance

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

a. Studies of Vestibular Functions	F. Guedry G. Crampton W. Collins	July 1956	Continuing

A study of the 'Coriolis vestibular phenomenon' in man has demonstrated a systematic relationship between the effective resultant Coriolis couple and the magnitudes of the subjective and oculomotor aspects of the vestibular reaction. The magnitude of inappropriate "Joystick" correction to be anticipated in attempts to recover from this source of disorientation ("vertigo") has also been estimated by this study.

A study of habituation to angular acceleration in cats has demonstrated that while a reduction in nystagmus can be partially overcome by alerting stimuli such as electric shock and auditory stimuli, neither of these is sufficient to bring the nystagmus back to its original intensity. Vestibular habituation is probably not attributable solely to a loss of alertness. Experiments involving surgical alteration of the cerebellum are being conducted to ascertain the importance of neuro-anatomical structures to the vestibular habituation process.

Experiments on man show that ocular nystagmus velocity increases like subjective velocity but whereas the latter declines after about 30 sec of stimulation, the former maintains magnitude until the stimulus terminates. The divergence of these two aspects of the vestibular reaction may be of significance in clinical neurology. The subjective estimating technique used has the added value of keeping the subject alert, which prevents intrusion of wandering unsystematic eye movements.

Experiments on the modification of the quantity and quality of nystagmus during controlled vestibular stimulation by assigning various mental tasks to human subjects have been completed. Mental activity was shown to have a powerful influence on nystagmic output. Techniques being developed will serve to increase precision of future experiments and eventually of clinical evaluation of the vestibular system.

The influence of visual stimulation on vestibular nystagmus and perceptual phenomena has been completed. This study shows that whereas a brief period of visual stimulation introduced during a moderate vestibular reaction is sufficient to correct the perceptual impression of apparent rotation with respect to the earth, the nystagmic reaction is only interrupted during the visual stimulation and recovers almost completely after termination of the visual stimulus. The results also bear upon habituation to vestibular stimulation in humans.

The ability to adapt to living in a continuously rotating environment was studied at the U. S. Naval Air Station, Pensacola, Florida, in seven men in an experiment conducted in cooperation with the U. S. Naval School of Aviation Medicine Research Department. Results showed that most subjects adapted, apparently satisfactorily, to a rotation scale of 5.4 rpm although all subjects except one were sick to the point of vomiting within the first twelve hours of the sixty-five hour run. By the last day the vestibular Coriolis perceptual phenomenon and the nystagmus normally elicited by head movements was greatly diminished. After the run was completed, head movements elicited nystagmus and subjective reactions of compensatory nature. These results bear on the habituation of human subjects to stimulation very similar to that anticipated in several military environments.

External - None

5. Special Sensory Functions in Relation to Performance

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

Project	Experimenter	Date Started	Estimated Completion
a. Studies in Vibration	G. Hawkes	Aug 1957	Continuing

Considerable work in communication by electrical stimulation of the skin of humans occurred. Absolute identification of two current intensity levels by the skin was shown to be feasible, with 87% accuracy shown when three intensity levels were utilized. Further work on pain and tolerance limits of the skin to current intensity revealed that intensities up to pain and tolerance limits could be used reliably for communication purposes without undue emotional reaction by the subject. More recent work investigates the role of stimulus duration in electrical stimulation of the skin. It was found that duration judgments for cutaneous stimulus were as accurate as auditory judgments and as reliable as auditory or visual judgments. Further refinement of basic psychophysical laws were experimentally derived during the year.

External -

	Project	Experimenters	Date Started	Estimated Completion
b.	Neural Correlates of Thermal Sensations	D.R. Kenshalo Fla State	Dec 1955	Aug 1961

Electrophysiological techniques are being used in exploring the thermal sensitivity of the cornea in the cat, preparatory to using infra-red radiation on human subjects. Data on the warm and cool thresholds as a function of the adapting temperature in humans has been gathered and remain to be related to data from prior studies. The crucial test to determine whether receptivity is located in neural endings or due to mechanical distortion in vascular changes remains to be done.

c.	Subjective Intensity Functions in Somes-thesis	F.N. Jones California	Sep 1958	Aug 1960

Previous difficulties with equipment were resolved with the perfection of an electronically controlled touch stimulator, control circuits, and monitor. The calibration of a new semi-conductor thermo couple junction for temperature stimulation was worked out. Subjective magnitude functions for touch were studied. It was concluded that rate of stimulus movement, over the range studied, was not a good stimulus dimension for purposes of magnitude estimation, and that the subjects judged the intensity of the touch stimulus according to the depth to which the skin was displaced.

d.	Psychological Influences of Gastro-Intestinal Activity	R.C. Davis Indiana	Sep 1959	Aug 1961

The effects of certain external conditions upon gastro-intestinal activity have been studied by the method of recording from external electrodes on abdominal sites. It was found that gastro-intestinal activity increases to a maximum within an hour after eating and in a resting state declines to a minimum 3-6 hours later, remaining at that level for 15-20 hours at least. Bodily position changes gastro-intestinal activity as does certain cognitive activities.

6. Integration of Complex Functions

Internal - U.S. Army Medical Research Laboratory, Fort Knox, Kentucky

a.	Studies of Complex Behavioral Processes	W. Gogel I. Behar G. Hawkes T. Cadwallader	Sep 1958	Continuing

Primate research was delayed by the departure of a primary investigator and inability to replace him until late in the year. A study of visual discrimination in primates showed that discrimination of the edges of two-inch cubes is superior to discrimination of the cube faces, with color as the discriminable cue. A recent study of the performance of rhesus monkeys on object-alternation problems shows four sources of difficulty in learning these complex problems: (1) low initial probability of selecting correct response, (2) difficulty in suppressing competing responses, (3) deficits in visual discrimination, (4) forced delay in the response. Recently begun are a series of studies on monkeys aimed at delineating cortical mechanisms important in visual discrimination.

Planned research into the effects of pyriform cortical lesions on animal behavior has been slowed. There has been considerable difficulty in constructing complex electronic conditioning equipment; this seems virtually overcome. More important, another problem previously thought to be irrelevant, the role of the type of metal in the surgical electrode, has to be solved. Recent work indicates that copper may cause larger and more enduring lesions than steel or silver. Work now underway will give information on this. Once these problems are settled, controlled work will again be taken up on conditioned behavior in relation to brain lesion.

Final studies on subtasks closed during the prior fiscal year are: (1) a study of human decision behavior which shows that increasing the number of response categories in a choice situation results in a relatively greater number of choices of the most frequently presented

stimulus, and (2) a collection of bibliographic materials concerning mechanical vibration and its effects on humans.

	Project	Experimenters	Date Started	Estimated Completion
External -				
b.	Factors Influencing Complex Decision-Making Behavior	R.H. Henneman Virginia	May 1954	Sep 1960

A number of separate experiments using task sequences of widely differing characteristics, have shown that recall performance progressively deteriorates with progressive increases in storage load, and when storage load is held constant, performance systematically improves with increases in load reduction. Other experiments have been largely concerned with the effects of several training variables (frequency of presentation, degree of distortion, knowledge of results) upon success of subsequent identification of stimuli at various levels of ambiguity.

c.	Context Effects in Psychophysical Judgments	W.E. Kappauf Illinois	July 1957	Sep 1960

Review of the literature has been extended to include trial-to-trial dependencies in psychophysical studies. An automatic programmer has been developed for use in studies of the discrimination of auditory duration and auditory loudness. A quantitative, rational analysis of several psychophysical methods has been conducted to determine the effect on adequacy of threshold determinations of size of stimuli steps in a comparison series. Another series of studies focussed on the conditions which influence context effects.

d.	Extreme Environment & Complex Performance in Primates	A.J. Riopelle Yerkes Labs	Feb 1960	Jan 1961

No report has been received to date since contract study was initiated only this year. Among the various extreme environments which will be studied will be high intensity noise. Further analysis will be attempted in regard to the mechanisms of the acoustic reflex.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

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4. U. S. ARMY ORDNANCE CORPS

I. U. S. Army Ordnance Human Engineering Laboratories, Aberdeen Proving Ground, Md.

A. CURRENT WORK PROGRAM

1. Supporting Research

The Supporting Research Laboratory, with three branches, supervises or conducts basic research to resolve human factors problems in the areas of: sensory inputs, predominately auditory and visual, but including other sense modalities; human outputs predominately in work fatigue; and abnormal or unusual environmental effects. The HEL supporting research program has been divided into five general technical areas: i.e., noise and blast; fire control; vigilance; radar; and vehicle confinement effects. The program has the following current tasks.

Project	Experimenters	Date Started	Estimated Completion
a. Effects of Weapon Systems Created Environmental Stresses on Crew Performance	A.A. Woodward	Dec 1959	Continuing

This task was initiated to study the effects of environmental stresses on crew efficiency. The study will incorporate the effects on human sensory and psychomotor performance as related to efficiency. Studies on thermal exchange, noxious fumes, odors, and air polution are planned for FY 61.

b. Vigilance	R. Karsh S. Glucksberg	June 1959	Continuing

This task was initiated to determine the relationship between basal skin conductance and vigilance behavior. A multi-phased in-house research study has been planned and partially accomplished. Among other results, an earlier study showed that there is significant relationship between galvanic skin resistance and attention level when a given type of intersignal interval is used. Current and future studies are aimed at determining the feasibility of the development of an automatic feedback system which could be used as part of a weapon system to alert a monitor of a degree of vigilance below a prescribed level.

c. Noise Measurement of R&D Items	R. Donley G. Goldstone G. Smith	Oct 1955	Continuing

This task was initiated to measure and determine the noise associated with the operation of Ordnance developed items in the prototype phase. A general methodology of measurement, frequency band analysis, and noise source isolation has been established. The objective is to isolate and identify noise sources whose intensities and frequencies have been found to interfere with voice communication and cause nausea, tinnitus or otherwise affect the efficiency of operating personnel. During FY 60, noise analysis of the T113 and M113 pilot production model APC's and a research sprocket for an M48 tank have been analyzed. Instrumentation has been developed and furnished to Ordnance inspectors to assist in production line noise level quality control. Currently, the noise level of the T196 self-propelled howitzer is being measured and analyzed. This will be a continuing task performed on new materiel.

d. Vision and Perceptual Research	C. Fried G. Moler	July 1958	Continuing

This task is to obtain data regarding man's ability to detect targets, estimate range with or without optical assistance, determine the effects of ECM, determine optimum operation symbols in radar displays, to determine the optimum method of presenting digital information and to determine the possible uses of the Kenetic Depth Effect technique. During FY 60, work was accomplished in all these tasks. Plans are presently being formulated for studies of accuracy of fire control from aerial platforms, range estimation and fire control using closed-circuit TV.

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	Project	Experimenters	Date Started	Estimated Completion
e.	Advanced Visual Information Display Techniques	McDonnel Aircraft Corp. St. Louis, Mo. J.I. Randall Technical Supervisor	June 1959	Continuing

This task was initiated as a contract study to develop a new technique for presentation of radar information at the fire unit level of operations. Such technique(s) are to be independent of the present state of the art development in radar displays but applicable to future antiaircraft and antimissile systems. This display system should use to the highest degree possible the human perceptual abilities and psychomotor skills in performing the assigned tasks of detecting, identifying, evaluating and engaging targets. The initial step, Phase I will be a feasibility study substantiated by sufficient diagrams and drawings to evaluate prior to initiation of Phase II - if justified - the fabrication of a bread-board.

f.	Effects of Control Delay in Operating a Remote Control Vehicle	J.D. Yelner G. Moler H. Wallach	Jan 1960	Jan 1961

This task was initiated to determine the effects of a time delay between the time that an operator initiates a signal to control a remote vehicle and the response of the vehicle to that signal. A remote control vehicle and associated equipment are being modified by the HEL to include the addition of a closed-circuit TV system. During FY 61, the vehicle will be used in remote control studies.

g.	Blast Measurement of Current and Future Ordnance Developed Weapon Systems	H.H. Holland, Jr.	June 1959	Continuing

This task was initiated to determine the blast overpressures found at the various crew positions of current and future Ordnance weapon systems. The goal is to establish an accurate measurement of the blast and the blast pattern so that the effects of different levels of blast can be applied to the ultimate design of weapon systems. In FY 60, measurements have been conducted on the 105mm Howitzer and 155mm Howitzer (105 and 155mm Howitzer Gun Improvement Program With and Without Muzzle Brakes), Infantry Assault Weapon, Light (LAW), DAVY CROCKETT, SERGEANT, and VIGILANTE. Items for FY 61 measurements are Medium Assault Weapon (MAW), Heavy Assault Weapon (HAW), RED EYE, SHALLEALAGH, as the materiel becomes available.

h.	Psychological and Physiological Effects of Muzzle and Breech Blast	J.J. Romba P. Martin L.A. Meister	Aug 1955	Continuing

This task was initiated to determine the potential psychological and physiological effects on operating personnel of muzzle and breech blast as experienced around current Ordnance weapon systems for application to future Ordnance weapon systems. This program should yield: (1) The physiological effects of blast with regard to pressure-time relationships; (2) Behavioral changes concomitant with the blast levels around Ordnance weapons and (3) Related behavioral changes due to blast and concomitant physiological changes. During FY 60, a study was completed in which the behavioral effects of 5 to 7 psi of blast were determined on Rhesus Monkeys. At the present time a study is being conducted to determine the effects of 7 to 15 psi. By the end of FY 61 this task should have yielded sufficient data in order to specify, in at least a general nature, the overall behavioral physiological and psychological effects of overpressures up to 15 psi. In addition to this study, additional research is being accomplished at the request of various developmental agencies on the blast effects associated with specific materiel.

i.	The Effects of Low Frequency, High Amplitude, Whole Body, Longitudinal and Transverse Vibration on Human Performance	Bostrom Research Labs, Milwaukee, Wis., I.A. Woods Technical Supervisor	Jan 1960	Jan 1961

This task is a continuation of a study sponsored by the Surgeon General. At present the Transportation Corps and the Ordnance Corps are jointly sponsoring a study to determine the effects on man's psychomotor performance of low frequency, high amplitude, whole body longitudinal and transverse vibration, inasmuch as all means of vehicular transportation subject the body to low frequency, high amplitude vibration. This environmental variable affects man's health, safety and performance efficiency. In FY 60, the contractor performed the first phase of the scheduled year's effort.

Project	Experimenters	Date Started	Estimated Completion
j. The Deleterious Effects of Impulse Noise	J.J. Romba M.G. Smith G. Goldstone	March 1959	Continuing

This task was initiated to determine the effects of high impulse noise on hearing created by current and new weapons. A pilot study using Rhesus Monkeys and human volunteers for the purpose of establishing audiograms prior to exposing them to safe limits of high impulse noise, i.e., wherein there is no permanent threshold change of hearing ability, has been established. During FY 60, equipment procurement and animal conditioning has been accomplished and a determination made that animal audiograms can be obtained with accuracy. Continuation of the program in FY 61 will be a determination of deleterious effects of impulse noise on human subjects.

Project	Experimenters	Date Started	Estimated Completion
k. Individual Capabilities and Limitations of Personnel Operating in Armored Vehicles	S.A. Hicks R.B. Randall	June 1959	Continuing

This task was initiated to determine the psychological and physiological capabilities and limitations of individuals and crews operating in tanks and armored personnel carriers for extended periods of time. As determined by a Department of the Army appointed committee, June 1959, this task represents the Ordnance Corps' portion of the total problem area. The task will include determination of the effects of periods of confinement up to and including 24 hours in duration, on the efficiency of performance of crews of armored vehicles. In FY 60, studies involving the effects of confinement of 4 hours duration has been completed and a report prepared; the effects of 8 hours confinement has been accomplished and a report is in preparation. The 4 hour confinement report reveals that statistically significant losses were found in the general areas of stamina, gross-motor coordination, equilibrium, eye-arm coordination and rifle firing accuracy. The 8 hour study results, although not published, substantially verifies the findings of the previous report.

2. Systems Research

The Systems Research Laboratory is organized into five branches. Four each having cognizance of a specific family of weapon systems or vehicles and one as a concept development branch. This laboratory serves as a contractor to all cognizant Ordnance developmental agencies, arsenals, and commands and maintains a continuing effort to provide to both in-house, i.e., weapon systems managers, and Ordnance prime contractors with the necessary specific human factors data and general human factors guidance to assure the development of the optimum man-machine relationship in weapon systems, including both operational and maintenance considerations.

The application of human factors engineering to weapon systems is conducted generally through an evaluation of concepts, engineering studies, prototypes development, and field evaluation taking into consideration: (1) Reduction or elimination of error-likely situations encountered in assembly of component items, handling equipment and check-out procedures; (2) The efficiency with which trained operators can set up and operate equipment; and (3) Environmental factors affecting the efficiency of the system and maintenance aspects. Projects vary in duration depending upon the requirements for human factors evaluation. In some cases only an end-item evaluation is required and in others a continuing evaluation is required Current projects being accomplished to provide research, support and application of human factors to the design, development and end-item evaluation of the weapons, vehicles and weapon systems are:

Project	Experimenters	Date Started	Estimated Completion
a. MAIN BATTLE TANK, Experimental Model	J.A. Stephens E.O. Judd J.S. Behrman G.L. Brown	Dec 1959	Continuing

This task involves both research studies and application of human factors in the development of the MAIN BATTLE TANK, XM. The initial work program has been divided into four aspects: (1) Evaluating the concept of the MAIN BATTLE TANK considering human factors; (2) Research studies to determine the feasibility of closed-circuit TV driving systems; (3) Investigating and developing a supine bed for use by the tank driver; and (4) Determination of surveillance requirements to include various types of closed-circuit TV and optical systems or a combination of these techniques.

b. M60 MAIN BATTLE TANK	C.G. Moler K.D. Foster	Aug 1959	Completed

The task was the performance of a human factors engineering end item evaluation of the design, operability, and maintainability of the MAIN BATTLE TANK, M60. The evaluation was initiated in FY 60. A report has been published.

c. Armored Reconnaissance Airborne Assault Vehicle (AR/AAV)	G.L. Brown C.G. White	Feb 1960	Continuing

During FY 60, an evaluation of a series of vehicular concepts was made and furnished the Ordnance Tank-Automotive Command. A concept was selected and plans are presently being formulated to perform human factors engineering support to the contractor during FY 61 and 62.

d. XM 70 Field Artillery Direct Support Weapon	J.P. Torre, Jr.	Jan 1960	Continuing

During FY 60, a preliminary evaluation of the operational procedures and a partial field evaluation of the system have been completed. A complete field evaluation of the system will be made in FY 61.

e. VIGILANTE System	R.T. Gschwind	May 1957	Continuing

During FY 60, efforts were directed to monitoring the development by the contractor of the various experimental prototypes of the VIGILANTE System and the preparation of test plans for a full scale field evaluation of the VIGILANTE System.

f. Wire Guided Missile Systems	F.M. McIntyre	June 1959	Continuing

During FY 60, an evaluation has been completed of the SS-11 system mounted on a $\frac{1}{4}$ ton 4 x 4 and a M59 APC, as well as a comparative evaluation of the efficiency of one operator vs. two operators in controlling a missile to the target. Minor efforts have been performed on other wire guided missile systems such as ENTAC, COBRA and VICKERS 891 to assist the weapon systems manager in evaluating these developments. Tentative plans have been established to participate in the mounting and firing of the SS-11 from a helicopter in FY 61.

g. 105mm Lightweight Howitzer	J.P. Torre, Jr.	Jan 1960	Continuing

During FY 60, effort on this weapon has been to provide consultation to Rock Island Arsenal on human factors associated with the development of a new lightweight 105mm howitzer. Plans were prepared to contribute to the research and development program in FY 61 and continue into FY 62.

h. Infantry Assault Weapon, Light (LAW)	R.T. Gschwind	April 1958	Continuing

This project involves in-house study and analysis of: sighting studies to determine the requirements for a throwaway sight unit; sound analysis of the rocket motor; a study of the operating instructions for the operator to be placed in decal form on the weapon; and an evaluation of the force required for trigger pull to assist in deriving manufacturing quality-control specifications. FY 61 effort will be to a redesign of the LAW weapon to be a one-piece launcher for further simplification.

Project	Experimenters	Date Started	Estimated Completion
i. 4.2 Mortar, T201	R.T. Gschwind J.P. Torre, Jr.	June 1960	Continuing

During FY 60, the plans for a human factors evaluation of the 4.2 Mortar with modified base plate have been completed and an outline of applicable human factors data compiled. During FY 61 the evaluation will be completed with recommendations for future mortar design.

j. SHILLELAGH Sub-System	F.M. McIntyre	Sep 1959	Continuing

This project is an in-house evaluation of the SHILLELAGH Sub-System as a component of AR/AAV and the MAIN BATTLE TANK, XM. During FY 60, primary effort has been in the area of coordination and guidance to the sub-system developers and conduct of studies in the areas of loading, tracking and developing an integrated sight unit for application to both the AR/AAV and MAIN BATTLE TANK, XM. FY 61 effort will be directed to inclusion of the SHILLELAGH Sub-System into AR/AAV.

k. DAVY CROCKETT System	R.T. Gschwind J.P. Torre, Jr.	Dec 1958	Continuing

This project is an in-house support study to evaluate the use of spotting rounds as a means of fire control technique and investigation of the feasibility or desirability of incorporating an inexpensive range finder to operate in conjunction with the spotting round technique. During FY 60, three spotting round studies were completed and plans are being completed to test the incorporation of an inexpensive range finder in conjunction with the spotting technique to be accomplished in FY 61.

l. SERGEANT Missile System	R F. Blackmer Bernard Jacobson	Jan 1958	Continuing

This is a continuing in-house effort. During FY 60, various components of the SERGEANT System were evaluated. Plans have been prepared and are currently being reviewed for the conduct of the operation and environmental tests for the first experimental model of the SERGEANT System. In addition to the FY 61 O&E tests planning, analysis and evaluation of communications requirements for the system and data insertion problems are being conducted. This program is tentatively scheduled for completion at the end of FY 62, in conjunction with a full scale field evaluation of the SERGEANT Missile System.

m. JUPITER Missile System	F.W. Wokoun, Jr.	Sep 1958	Completed

During FY 60, an evaluation of the mobile training unit designed to permit complete operator training for the JUPITER System has been completed. This program will phase out in the first quarter FY 61.

n. LITTLE JOHN Launcher	T.B. Pomeroy	Feb 1960	Completed

During FY 60, a field evaluation of two models of the LITTLE JOHN Launcher, i.e., PADA and SOSR, has been completed and a report written. At the present time, no further work has been projected on this system.

o. LACROSSE Missile System	T.B. Pomeroy	Sep 1958	Completed

This is the completion of a four-year continuing project wherein the system has been field evaluated and component redesign recommendations made in a final report presently being published to the weapon systems manager.

Project	Experimenters	Date Started	Estimated Completion
p. PERSHING Missile System	J.R. Erickson B.L. Sova, Jr.	Oct 1958	Continuing

During FY 60, in-house effort has been accomplished to include: (1) Evaluation of each of the major components of the PERSHING System; (2) Evaluation of mock-ups and components; (3) Evaluation of preliminary count-down procedures; and (4) Plans and preparations for a field evaluation of the erector launcher and an evaluation of the communications system to include the communication hut. Plans for continuation of the above effort during FY 61 are being made in conjunction with work accomplishment.

q. RED EYE Missile System	F.W. Wokoun, Jr.	Nov 1958	Continuing

During FY 60, the research effort has been on an evaluation of the procedures for employment of the RED EYE Missile System; monitoring the contractor's efforts in the physical design of the system; a complete study to determine the feasibility of utilizing a dual configuration; and the operator's ability to detect airborne targets. A report has been published concerning an operator's ability to detect airborne targets. During FY 61, efforts will be a continuation of the concept development study, operational factors, check-out procedures and noise evaluation of the rocket motors.

r. MAULER System	G.L. Kurtz	May 1960	Continuing

FY 60 work has been limited to an evaluation of the concept proposals to assist the weapon system manager's decision in selecting a development contractor, and coordination for the R&D program beginning in FY 61.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

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CARMODY, DANIEL F., SP4, Biological Sciences Assistant, BS, Saint Norbert College, 1958.

CLARK, LUCIUS V., PVT., Project Engineer, BS, New Mexico Institute of Mining and Technology, 1959.

CRUSE, CHARLES, Chief, Engineering Research Laboratory, Maryland Institute School of Mechanical Arts.

DEERING, LAWRENCE E., Engineer (Human Factors), BS, University of Maine, 1920.

Di BIASE, JAMES J. Jr., RCT, Project Engineer; BS, University of Maine, 1960.

DOHERTY, WILLIAM J. Jr., 1st Lt., Research and Development Coordinator; BS, Boston College, 1958.

DONLEY, RAY, Engineer (Human Factors); ME, University of Cincinnati, 1954.

EKSTROM, RAYMOND M., SP4, Electrical Engineer Assistant; AEE, Wentworth Institute, 1958.

ERICKSON, JOHN R., Engineer (Human Factors); BS, Case Institute of Technology, 1951.

FAIR, PAUL A., Engineer (Human Factors); Certificate, Pratt Institute, 1926.

FRIED, CHARLES, Research Psychologist (Physiological, Experimental and Engineering); MA, New School for Social Research, 1953.

GARINTHER, GEORGE R., Engineer (Human Factors); BS, Gannon College, 1957.

GLUCKSBERG, SAM, 2d Lt., Psychologist; PhD, New York University, 1960.

GOLDSTONE, GERALD, Psychologist; MA, MacMurray College, 1958.

GSCHWIND, ROBERT T., Engineer (Human Factors); BS, Lehigh University, 1956.

HICKS, SAMUEL A., Research Psychologist (Physiological, Experimental and Engineering); BS, Morgan State College, 1956.

HODGKISS, WILLIAM, SP5, Project Engineer; Certificate, Purdue University, 1960. (Army Ordnance Technician Program, Electronics Technician Course)

HOLLAND, HOWARD H., Engineer (Human Factors); BS, Virginia Polytechnic Institute, 1942.

HORLEY, GARY L., Engineering Design Technician (Human Factors); BFA, Philadelphia Museum School of Art, 1956.

HOUFF, CHARLES W., Lt Col, Deputy Director; Human Engineering Laboratories, University of Virginia, University of Maryland.

JACOBSON, BERNARD, Research Psychologist (Physiological, Experimental and Engineering); MS, Iowa State, 1957.

JUDD, EDWARD O., 1st Lt., Research and Development Coordinator; MA, Purdue University, 1959.

KARSH, ROBERT, Research Psychologist (Physiological, Experimental and Engineering); BA, Brooklyn College, 1957.

KATCHMAR, LEON T., Chief, Systems Research Laboratory; PhD, University of Maryland, 1954.

KLEIN, HUGO L., 1st Lt., Research and Development Coordinator; BBA, St. Mary's University, 1958.

KRAMER, RICHARD R., Physicist (General); BA, Williams College, 1956.

KURTZ, GARY L., Electronic Engineer; BSEE, Pennsylvania State University, 1959.

MAFFIA, PAUL M., 1st Lt., Research and Development Coordinator; BS, Loyola University, 1958.

MARTIN, PAUL, SP4, Personnel Psychologist Specialist; MA, Loyola University, 1958.

MEISTER, LAWRENCE A., PFC, Personnel Specialist; BA, University of Iowa, 1957.

McCAIN, CLAUDE N., Jr., R.P.E., Assistant Chief, Supporting Research Laboratory; BS, University of South Carolina, 1950.

McELVENNY, BERNARD J., Engineer Technician; BA, St. Joseph's College, 1954.

McINTYRE, FRANCIS M., Research Psychologist (Physiological, Experimental and Engineering); MA, Temple University, 1958.

MOLER, CALVIN G., Engineer (Human Factors); BSEE, Davis and Elkins College, 1950.

NORLANDER, WILLIAM D., Mechanical Engineer Assistant; BS, Lehigh University, 1959.

PETTIT, GEORGE D., Electrical Engineer (Instrumentation); BSEE, North Carolina A&T, 1949.

POMEROY, THOMAS E., SP4, Project Engineer; BA, Michigan State, 1958.

PORTER, WILLIAM J., Physical Science Assistant; BS, Duquesne University, 1959.

RALSTON, GLENN B., PFC, Personnel Specialist; BA, Depauw University, 1958.

RANDALL, JAMES I., Assistant Chief, Engineering Research Laboratory; BS, Johns Hopkins University, 1958.

RANDALL, RUSSELL B., PFC, Personnel Specialist; BA, Alma College, 1959.

ROMBA, JOHN J., Research Psychologist (Physiological, Experimental and Engineering); MA, University of South Dakota, 1955.

SMITH, M. GLENN, Research Psychologist (Physiological, Experimental and Engineering); MS, Lehigh University, 1960.

SOVA, B. LAWRENCE, Jr., Engineer (Human Factors); BS, Worcester Polytechnic Institute, 1955.

STEPHENS, JOHN A., Assistant Chief, Systems Research Laboratory; BES, Rhode Island School of Design, 1951.

SZEMPLAK, JEROME C., SP4, Mechanical Engineer Assistant; BME, General Motors Institute, 1958.

TORRE, JAMES P., Jr., Research Psychologist (Physiological, Experimental and Engineering); BA, Adelphi College, 1954.

UPTON, MORGAN, Consultant; PhD, Harvard University, 1928.

Von UFFEL, WILLIAM W., Jr., SP4, Mechanical Engineer Assistant; BFA, Philadelphia Museum School of Art, 1959.

WALLACH, HAROLD C., Research Psychologist (Physiological, Experimental and Engineering); MS, University of Michigan, 1958.

WEISS, ROGER M., 2d Lt., Research and Development Coordinator; BS, Lehigh University, 1959.

WEISZ, JOHN D., Director, Human Engineering Laboratories; PhD, University of Nebraska, 1953.

WHITE, CHARLES G., SP5, Project Engineer; Certificate, Purdue University, 1960. (Army Ordnance Technician Program, Electronics Technician Course)

WOKOUN, F. WILLIAM, Research Psychologist (Physiological, Experimental and Engineering); PhD, University of Nebraska, 1959.

WOOD, BENJAMIN F., Jr., Engineer (Human Factors); BSME, West Virginia University, 1950.

WOODS, IRVING A., Chief, Supporting Research Laboratory, PhD, American University, 1954.

WOODWARD, ARTHUR A., Jr., Physiologist (Human Factors Engineering); PhD, University of Pennsylvania, 1947.

YOUNG, ROBERT R., Mechanical Engineer; BS, Bucknell University, 1960.

II. Picatinny Arsenal, Dover, New Jersey

A. CURRENT WORK PROGRAM

1. Basic Project Work

Human Factors Specialists are working members of the "design team" for the warhead section phases of the following nuclear projects:

a. PERSHING
b. LITTLE JOHN
c. SERGEANT

The participation in team design efforts extends also to the DAVY CROCKETT Project, SHILLELAGH, XM-51 Rocket Motor Production Engineering, and other classified items.

(1) Analysis of Tasks
(2) Personnel requirements
(3) Training requirements
(4) Manuals and check sheets
(5) Test equipment
(6) Handling equipment
(7) Packing and shipping
(8) Assembly
(9) Work space layout
(10) Maintenance
(11) Pre-and-In-Flight activities
(12) System synthesis
(13) Environmental conditions

The methods used are both analytical and empirical, and the results consist of detailed design recommendations for the consideration of, and the implementation by, the project manager.

2. Support Programs

a. Projectile, 155mm, (T-358). Research is being conducted to determine an optimal diameter for the MT fuze setting shaft; the size, color, and sequence of the option selector switch; a suitable wrench for connecting the VT fuze; gear ratios for the time setting screw; and other pertinent items.

b. Case, Atomic Demolition Charge (XM-113). Several problems are being studied as regards obtaining torque requirements within critical limits; time settings and displays; and other items of a classified nature.

c. Increment Bag Holders, 81mm Mortar Shell (M362). This study was initiated in an effort to derive a method of attaching increment bags which will minimize attachment time and maximize holding ability.

3. Special Studies

A special study is being initiated to investigate the relationship between load-carrying weight and position, and recovery rate after dropping the load. Whereas, there have been many studies of load-carrying, few, if any, have concerned themselves with combat effectiveness after a long and difficult load-carrying task has been completed. A prominent portion of this investigation concerns itself with development of criteria. Measures of body metabolism and several perceptual-motor tasks are being considered.

4. Systems Analysis

Although studies of this sort may include an experimental phase, they are primarily analytical in nature. Currently, a study is being conducted of the effectiveness of a new type of anti-personnel mine in terms of patterns and density of dispersion; optimal external, physical characteristics; and methods for distributing and recovering the item. Experimental aspects of the system include human requirements for arming and safing the device, as well as training requirements.

A second system under investigation concerns aerial delivery of anti-tank mines. This analysis deals with methods of delivery, identification of various types of mines, troop requirements and subsequent recommendations for optimal techniques.

5. Miscellaneous Activities

Consultation. Almost $\frac{1}{2}$-man/year per year is devoted to consulting with design personnel on matters of optimal design of equipment; incidental matters involving psychological, biological, or anthropological and physical data; or in disseminating information relative to human factors. In addition, periodic human factors bulletins are distributed which discuss recent topics of widespread interest and which inform R&D personnel of available human factors engineering resources.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Evaluation of the Probability of Detection of the T 1200E2 Fuze and Tilt Rod.

Human Factors Analysis of Target Location Errors (In press).

Human Factors in Rangefinding and Range Estimation.

Human Factors Analysis of 81 mm Mortar Increment Bag Holders (In press).

Man-Portability of Portapack A, XM 28 Weapons System.

Field Study of Portapacks B & C, XM 28 Weapons System (In press).

Field Study of XM 29 Weapons System (In press).

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

BESSEY, G. PAUL, Mechanical Engineer; BSIE, Bradley University, 1953.

BLACKWELL, SAMUEL A., Psychology Assistant; BA, Gettysburg College, 1958.

GLASS, ALBERT A., Supervisory Psychologist (Human Engineering); MA, New York University, 1950.

KOSTAKIS, JOHN, Psychology Assistant; BA, City College of New York, 1959.

MYDOSH, JOSEPH, Cooperative Student (Attending Drexel Institute).

III. Watertown Arsenal, Watertown 72, Massachusetts

A. CURRENT WORK PROGRAM

1. Launcher, 762MM Rocket, XM 33E1

2. 37MM AA Gun Carriage, T112

3. Launcher, E42R2 Rocket, XM 86

The above projects represent a continuing effort to insure implementation of human factors requirements in the design, to result in an efficient man-weapon relationship.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

HUGHES, THOMAS D., Mechanical Engineer.

IV. U.S. Army Ordnance Weapons Command, Rock Island, Illinois

A. CURRENT WORK PROGRAM

LITTLE JOHN Launchers, XM 34 and XM 80
115mm Launcher, XM 70
Howitzer, 105mm Towed, Lightweight

The Human Factors Engineering program is one of coordination of studies performed on mission items by the member arsenal and of reviewing projects and technical reports in order to assist the arsenals in their development programs.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

LORENZEN, THEODORE G., Jr., Mechanical Engineer (Ordnance Weapons Human Engineer); BS, Bradley University, 1951.

V. U. S. Army Ordnance Missile Command, Army Rocket and Guided Missile Agency, Redstone Arsenal, Alabama.

A. CURRENT WORK PROGRAM

LACROSSE (Martin-Orlando, HEL)
SERGEANT (SUEL, JPL, HEL)
RED EYE (Convair, HEL)
MAULER (Convair, HEL)
HAWK (Raytheon Corp, Dunlap & Assoc, HEL)
NIKE HERCULES (BTL, DAC)
LAW (Hesse-Eastern, HEL)
NIKE ZEUS (BTL, DAC)
Advanced Visual Information Display Study (HEL, McDonnell Aircraft Corp.)

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

GRAHAM, DONALD I., Jr., Technical Advisor, Field Protective Measures and Human Engineering; CE, Northwestern University, 1937.

VI. Ordnance Tank-Automotive Command, Detroit Arsenal, Center Line, Michigan

A. CURRENT WORK PROGRAM

Vehicle Ride Characteristics. (Univ. of Michigan)

Human Engineering Studies on a New Main Battle Tank (HEL)

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

D'ANGELO, HORACE Jr., 1st Lt., Research & Development Coordinator; BA, Michigan State University, 1957.

KREUCHER, RAYMOND N., Chief, Systems Analysis Section; BS, Mechanical Engineering, Lawrence Institute of Technology, 1947.

LASKARIDES, SAVAS, Automotive Research and Design Engineer; BS, Carnegie Institute of Technology, 1946.

VAN THIELEN, PAUL R., Chief Development Engineer; General Motors Institute.

VII. Frankford Arsenal, Philadelphia 37, Pa.

A. CURRENT WORK PROGRAM

Project	Experimenters	Date Started	Estimated Completion
1. Heavy Anti-tank Weapon System - XM-89	W. Gaymon L. Gallun	May 1959	May 1961

This major effort on this project was directed toward the design and conduct of experiments to investigate certain human engineering problem areas encountered in the operation of the XM-89 System. The specific goal of the studies was to determine the optimal control friction and control ratio values which would lead to maximum system performance. These studies involved live firing of Sub-caliber spotters.

Control friction and control ratio were varied through a representative range of values, in respective studies, and total man-machine system performance was measured at each value using the BAT System as a comparison. The two systems (XM-89 and the BAT) were compared against moving and stationary targets.

A research report is nearing completion in which complete accounts of the above mentioned studies will be presented. Data will be offered to support the selection of certain control friction and control ratio values for the final system. The results of the studies show the XM-89 System to be generally superior to the BAT on the majority of criteria considered.

Studies are currently being designed to investigate additional human engineering aspects of the XM-89 System. With the use of simulated tracking equipment the following problems will be studied in the very near future:

a. The effect, if any, on performance of weight imbalance created by firing on the main round.

b. The effect on performance of firing the weapon with the trigger and sighting mechanism relocated to the right-hand side of the weapon.

An improved reticle design is also under consideration and the problem is to be investigated through coordination with the Mathematics Branch.

2. Field Artillery Digital Automatic Computer System	1st Lt R.P. Johnston	Sep 1959	June 1961

This system offers the possibility of handling the computations for, and the issuance of, fire commands by the artillery fire direction center in a semi-automatic manner. Thus far the Human Factors Engineering effort has been of a consultant nature. Areas investigated include the orientation, size of lettering, & abbreviations necessary for maximum discrimination and clarity and the arrangement of hardware entry buttons and display indicators consistent with operator utilization and logical sequence of operation.

Project	Experimenters	Date Started	Estimated Completion
3. Davy Crockett	R.P. Johnston E.J. McGuigan	Sep 1958	June 1961

This project involves the human engineering evaluation of two weapon systems. Due to the security aspects of the project, the evaluation of the systems can only be discussed in general terms.

The work to date has been a consideration of four potential problem areas: (1) Location of controls; (2) Man portability; (3) Operation of system, including speed and accuracy in normal and extreme environmental conditions; (4) Maintenance and safety, including such considerations as minimum number of tools necessary to effect "in field" maintenance, ease of maintenance, ruggedness of system under conditions of climatic extremes and prolonged usage.

4. Medium Anti-tank Weapon - M67 Recoilless Rifle	R.F. Kelly	Sep 1959	June 1961

The M67 is a shoulder-fired anti-tank weapon which will use a spotting rifle to obtain a high hit probability with the first major round. Since the weapon cannot be readily traversed in its ground-supported position, in order to engage moving targets it must be fired from the shoulder. In this position, difficulty is expected in maintaining the sight picture until an error feedback is obtained from the spotter round.

The major human engineering problems involved in this project are as follows: (1) Determination of the best technique for utilizing the spotter. It may be necessary to evolve an entirely new concept of spotter usage. (2) Improvement of the inherent steadiness and usability of the weapon by determining the best design and location of the trigger grip, shoulder rest, spotting rifle, sight and forward support (monopod).

The following experimental work is being planned:

a. Tracking studies using the simulated tank tracking system in the laboratory. A mock-up is being constructed which will have the same weight and "feel" as the weapon itself for use in these tracking studies. The locations of the trigger grip, sight, monopod, etc. are adjustable so that various positions can be tried.

b. Live firing of the weapon using spotting pistol.

These experiments will be designed to obtain as much data as possible with respect to each of the above problems.

5. Electro-Visual Equipment	G. Rowland A.C. Karr	June 1958	June 1961

This system offers the possibility of night-time tank operations through the use of electro-visual equipment (closed circuit television capable of operating in low levels of illumination). The major human engineering problem areas concern controls and display. The visual problems inherent in using night-time television for surveillance, target detection, and weapon laying are quite unique and require extensive investigation.

Present plans call for two laboratory experiments to be followed by static and dynamic field tests. The purpose of the first laboratory experiment is to determine the optimal display conditions for detecting and identifying targets. The second experiment has two purposes: (1) To determine if the basic design parameters of this system will work; (2) to identify the critical variables and their interactions. The static field tests will provide specific data on performance with electro-visual equipment vs vision aided by standard optical equipment. These tests will also test the presently envisaged operational procedures regarding activity sequences, inter-crew member coordination and communication.

The dynamic field tests will evaluate the system under combat-like conditions.

6. Main Battle Tank	G. Rowland A.C. Karr	June 1960	June 1963

The purpose of this project is to provide human engineering services for the fire control of the Main Battle Tank. The work of the Human Factors Engineering Section is concerned primarily with monitoring contractor efforts and coordinating the work of the Human Engineering Laboratories, Frankford Arsenal, and the contractors. Certain problems in the use of television will also be investigated.

Project	Experimenters	Date Started	Estimated Completion
7. Tank Tracking	A.C. Karr	Nov 1957	Continuous

An electronic tank tracking system has been designed and constructed. This equipment is used in conjunction with mock-ups of new anti-tank weapon systems to obtain human engineering data to be used as design criteria. Experiments in progress are designed to determine the optimal control characteristics for joy-stick controlled anti-tank weapon systems.

8. Fire Control Consultation Services	Staff	Sep 1959	Continuous

Separate funds have been set aside by the Fire Control Division for human engineering consultation services that will not require more than 2 man weeks of effort. Where more effort is required, a separate project is to be set up for it. These funds permit project engineers to request the Human Factors Engineering Section to look into their projects and determine how much human engineering is required, outline a complete program to be followed, and provide assistance in obtaining human engineering data through literature searches and experimentation.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE

Report No. M60-25-1 Human Engineering Evaluation of XM29 Delivery System (U) (CONFIDENTIAL), A. Charles Karr, March 1960.

In Press Human Engineering Evaluation of XM 89 (U) (CONFIDENTIAL), Dr. George E. Rowland, September 1960.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

GALLUN, LOUIS, Engineering Technician (Ordnance)

GAYMON, WILLIAM E., Research Psychologist; MS, Howard University, 1956.

JOHNSTON, ROBERT P., 1st Lt., Mechanical Engineer; BS, University of Illinois, 1958.

KARR, A. CHARLES, Supervisory Psychologist; MA, Lehigh University, 1953.

McGUIGAN, EUGENE J., Psychologist; BA, Temple University, 1950.

ROWLAND, DR. GEORGE E., Consultant; PhD, Ohio State University, 1951.

VIII. Rock Island Arsenal, Rock Island, Illinois

A. CURRENT WORK PROGRAM

Human Engineering Evaluation of LITTLE JOHN and HONEST JOHN rocket launcher systems.

Auxiliary Propelled 155mm Howitzer Concept Studies of new lightweight 105mm Howitzer Carriage and 115mm Boosted Rocket Launcher, XM 70.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

FREYMANN, EDWARD, General Ordnance Design Engineer.

HEIDEL, WILLIAM, Carriage Design Engineer; BSME, Bradley University, 1951.

HERSHMAN, CLARK, Engineering Designer.

RAISBECK, LEO, Mechanical Engineer; BSME, University of Illinois, 1949.

JOHNSON, WILLIAM A., Ordnance Design Engineer.

IX. Springfield Armory, Springfield 1, Massachusetts

A. CURRENT WORK PROGRAM

Weapon Weight Distribution Program

Sight Configuration Study

Weapon Stock Study

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

LIZZA, ALBERT J., Mechanical Engineer, Ordnance; MS, University of Massachusetts, 1958.

ROCHA, JOHN G., Mechanical Engineer; BS, New Bedford Institute of Technology, 1952.

X. U. S. Army Ballistic Missile Agency, Redstone Arsenal, Alabama

A. CURRENT WORK PROGRAM

1. Internal

JUPITER - Support in the field of human factors engineering for analysis, design and evaluation of the mobile training units.

PERSHING - Analysis, design and evaluation, from a human factors engineering viewpoint, of the missile, ground support and maintenance equipment and pertaining field operations.

The Human Engineering Laboratories is providing design assistance and evaluation support services on PERSHING and JUPITER.

2. External

PERSHING - PERSHING Development Specification for Weapon System Human Factor Design Criteria. (The Martin Company)

PERSHING - Task and Skill Analysis for the PERSHING Missile System, Vol 2, Training and Training Aids. (The Martin Company)

PERSHING - A Human Factors Engineering Evaluation of the PERSHING Weapon System, the '59 Transporter-Erector-Launcher. (Human Engineering Laboratories)

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

None.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

CHAIKIN, GERALD, Coordinator, Human Factors Engineering; BS, Purdue University, 1956.

COYNE, JAMES F., Mechanical Engineer Assistant; BS, 1958.

KORACH, I. S., Mechanical Engineer Assistant; BS, 1959.

5. U. S. ARMY QUARTERMASTER CORPS

I. U. S. Army Quartermaster Research and Engineering Center, Natick, Mass.

A. CURRENT WORK PROGRAM

1. Human Engineering and Compatibility Studies of QMC Items

Title	Experimenters	Date Started	Estimated Completion
a. Development of Methods for the Study of Human Factors Important for Soldier Compatibility With and Efficient Use of QMC Items	J. McGinnis	Jan 1959	Continuing

Techniques have been developed for identifying and analyzing incompatibilities found in man-machine systems. These techniques provide a convenient and systematic method for identifying incompatibilities and evaluating their severity and importance. Further work is planned to increase the efficiency and broaden the applicability of the techniques.

Title	Experimenters	Date Started	Estimated Completion
b. Determination of Major Areas of Incompatibility Between the QMC-equipped Soldier and Developmental Signal Corps and Ordnance Corps Items	G. Rosinger	Jan 1959	Continuing

The aim of these studies is to prevent incompatibilities between Quartermaster clothing and equipment and missile and other weapons and communications systems. The emphasis is on providing to designers of clothing and weapons relevant information secured from cold weather and other tests.

Title	Experimenters	Date Started	Estimated Completion
c. Human Factors Analysis of Psychoacoustical Requirements for Military Headgear	A. Cohen	July 1959	Continuing

These studies include collation of information on noise levels associated with military vehicles and weapons, investigation of the effects of continuous and impulse noise on the hearing of pure tones and speech, and the effect of helmet shell configuration on sound suppression properties.

Title	Experimenters	Date Started	Estimated Completion
d. Human Factors Analysis of Means of Protecting Visual Function from Extreme Environmental Stresses	J. Kobrick	Feb 1960	Dec 1960

Studies are being made of the effects of wind-temperature combinations upon visual performance in order to determine possible limits of environmental exposure of the eyes. The results will be applicable to development and use of functional military headgear and facegear.

Title	Experimenters	Date Started	Estimated Completion
e. Human Factors Study of Visual, Acoustical, Ballistic, and Crash Protection for Army Aircraft and Aircrew Systems	J. Senna	Jan 1959	June 1961

Work is continuing to determine techniques for providing passive protection to the aircrews of new aircraft and to determine factors in the aircraft environment which affect pilot performance.

Title	Experimenters	Date Started	Estimated Completion
f. Human Factors Study of the Design, Operation, and Maintenance of Materials Handling Equipment	B. Crist	Jan 1959	June 1961

Human engineering guidance is being furnished on the new Sandfly forklift truck series.

Title	Experimenters	Date Started	Estimated Completion
g. Study of Techniques for Reducing Performance Decrements Produced by Handwear	J. Kobrick	Nov 1958	Jan 1961

Studies are planned to investigate types of materials and methods of handwear design which can be used to construct handwear which will permit increased tactical sensitivity and dexterity.

h. Analysis of Hand Movements Essential for Accomplishing Military Tasks	J. Kobrick	Jan 1960	June 1961

Realistic development of manual performance tests and hand protection gear requires knowledge of what soldiers do with their hands. A preliminary analysis has been made of hand movements during field communications activities. Further studies are planned.

i. Human Engineering Support	R. Dusek	July 1960	Continuing

Evaluations, assistance, and guidance in support of item development are furnished as requested.

2. Studies to Provide Anthropometric Design Guidance and Realistic Design Criteria for QMC Items

a. Collection and Analysis of Anthropometric Data Concerning Functional Characteristics of the Military Population	R. Newman	Jan 1958	Continuing

Range of movement, spatial dimensions, and other functional characteristics of the military population are being determined to provide anthropometric criteria and guidance for the design and development of QMC items. Head and face dimensions, ankle and foot contours, and special hand dimensions are being studied.

b. Anthropometric Measurements of Army Aviators	R. White	July 1959	Dec 1960

Anthropometric measurements of a representative sample of Army aviators are undergoing analysis to establish realistic criteria for the design and sizing of materiel and equipment.

c. Anthropometric Design and Sizing Guidance	R. White	1948	Continuing

Tariffs are developed and design guidance is furnished as requested in support of clothing and equipment developmental programs.

3. Systematic Investigation of the Psychological and Physiological Reactions of the Soldier to the Stresses of Natural and Military Environments.

a. Determination of the Psychological and Psychophysiological Effects of Environmental Stresses on the QMC-equipped Soldier	B. Fine	July 1959	Continuing

Studies are being conducted on the effects of auditory stimulation on perception of the vertical and on the effects of high humidity at high and moderate temperatures on soldier motor and intellectual performance.

	Title	Experimenters	Date Started	Estimated Completion
b.	Study of Factors Important for Efficient Hand Performance at Extreme Temperatures	R. Clark	Jan 1959	Dec 1960

Studies are being made of the effects of hand skin temperatures, duration of exposure to the cold, and the temperature at which the task is learned on five finger dexterity. Limiting skin temperatures for unaffected hand performance are being determined also.

c.	Exploration of the Value, as Indices of Strain Imposed on the Soldier by Natural and Military Environments, of Individual and Group Psychological Measures	B. Fine	July 1959	Continuing

The MMPI derived Internalization Ratio (IR) is being used for predicting satisfactory test subject performance, both in the QM R&E Command test subject pool and in a Greenland field exercise. Work is continuing on the IR and also on the MMPI derived Anxiety Index (A.I.).

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Clark, R. E. The calculation of mean hand skin temperature in studies of manual performance in the cold. EPRD Res. Study Rept. PB-29, U. S. Army, QM R&E Command, Natick, Mass., Oct. 1959.

Clark, R. E. and A. Cohen. Manual performance as a function of rate of change in hand skin temperature. J. Appl. Physiol., 1960, 15(3), 496-498.

Cohen, A. Psychoacoustic and comfort properties of helmet communications gear. EPRD Tech. Rept. EP-123, U. S. Army, QM R&E Command, Natick, Mass., Jan. 1960.

Cohen, A. Sound transmission through the Combat Vehicle Crewman's helmet when the seal of the earpads is broken. EPRD Res. Study Rept. PB-39, U. S. Army, QM R&E Command, Natick, Mass. (In press.)

Cohen, A. and J. F. Corso. Further assessment of the effects of intensity on the pitch of pure tones. J. Acoust. Soc. Amer., 1959, 31, 1565.

Cohen, A. and B. J. Fine. Auditory discrimination and sleep deprivation. J. Acoust. Soc. Amer., 1960, 32, 925.

Corso, J. F. and A. Cohen. Methodological aspects of absolute auditory threshold measurements. J. Exp. Psychol., 1958, 55, 8-12.

Fine, B. J., A. Cohen and B. Crist. Effect of exposure to high humidity at high and moderate ambient temperature on anagram solution and auditory discrimination. Psychol. Reports, 1960, 171-181.

Gardner, R. A. Multiple-choice decision-behavior as a function of the number of response categories. USAMRL Report No. 408, Dec. 1959.

Gardner, R. A. Two-choice decision-behavior and the number of alternative critical events. USAMRL Report No. 438, 1960. (In press)

Gardner, R. A. A note on theory and methodology in the study of figural aftereffects. Psych. Rev. 1960. (In press)

Gardner, R. A. Immediate and residual figural aftereffects in kinesthetic judgements. Amer. J. Psychol., 1960. (In press)

Hooton, E. A. Body build in a sample of the United States Army. Part I: Body build in relation to military function. Part II: Measurements of body build. EPRD Tech. Rept. EP-102, U. S. Army, QM R&E Command, Natick, Mass., Feb. 1959. (Dept. of Anthropology, Harvard University Contract Nos. W44-109-QM-1078 and W44-109-QM-2014.)

Kobrick, J. L. and B. Crist. QM human engineering handbook series: VII: The size and shape of the available visual field during the wearing of Army headgear. EPRD Tech. Rept. EP-133, U. S. Army, QM R&E Command, Natick, Mass., May 1960.

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C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

CLARK, RUDOLPH E., Dr., 1st Lt., Medical Service Corps, Research Psychologist, Psycho-physiology Section; PhD, University of Iowa, 1958. Area of specialization: Physiological factors in learning and performance; motivation.

COHEN, ALEXANDER, Dr., Research Psychologist, Human Engineering Section; PhD, Pennsylvania State University, 1959. Area of specialization: Engineering psychology; hearing and speech.

CRIST, BRIAN, Research Psychologist, Human Engineering Section; MA, Boston University, 1957. Area of specialization: Vision; hearing; apparatus design.

DUSEK, E. RALPH, Dr., Chief, Psychology Branch; PhD, State University of Iowa, 1951. Area of specialization: Physiological psychology; psychomotor performance.

FINE, BERNARD J., Dr., Chief, Psychophysiology Section; PhD, Boston University, 1956. Psychophysiology; social psychology with emphasis on attitude change, personality and small groups.

GARDNER, R. ALLEN, Dr., Research Psychologist, Psychophysiology Section; PhD, Northwestern University, 1954. Area of specialization: Perception; learning.

JONES, CLARK E., Research Psychologist, Human Engineering Section; MS, Pennsylvania State University, 1949. Area of specialization: Physiological psychology.

KOBRICK, JOHN L., Dr., Chief, Human Engineering Section; PhD, Pennsylvania State University, 1953. Area of specialization: Engineering psychology; apparatus design; learning.

McGINNIS, JOHN M., Dr., Chief, Systems Research Section; PhD, Yale University, 1929. Area of specialization: Human factors in system design; environmental psychophysiology; attitude measurement.

NEWMAN, RUSSELL W., Dr., Chief, Anthropology Branch; PhD, University of California, 1949. Area of specialization: Applied physical anthropology.

PELKEY, WILLIAM E., 2nd Lt., QMC, Research Psychologist, Systems Research Section; AB, University of Maine, 1958. Area of specialization: Experimental psychology.

ROSINGER, GEORGE, Research Psychologist, Systems Research Section; MA, Lehigh University, 1959. Area of specialization: Applied experimental psychology; human factors engineering.

SENNA, JOZEF F., Captain, QMC, Research Psychologist, Systems Research Section; MA, Ohio State University, 1959. Area of specialization: Human factors problems in systems operations; engineering psychology.

WHITE, ROBERT M., Physical Anthropologist, Anthropology Branch; BS, Haverford College, 1939. Area of specialization: Applied physical anthropology.

II. U. S. Army Quartermaster Food and Container Institute for the Armed Forces, Chicago, Illinois.

A. CURRENT WORK PROGRAM

1. Research on Attitudes Toward and Acceptance of QMC Materiel

Title	Experimenters	Date Started	Estimated Completion
a. Effect of Non-functional Attributes of Products on Acceptance	J. Kamen	March 1960	Continuing

The role of factors such as packaging, color and labeling on acceptance or use of materiel is being studied in order to determine if acceptance can be increased by methods not requiring training or indoctrination. Currently the effects of such devices as a "seal of approval" on attitudes toward a product are being investigated.

b. Role of Feeding Procedures in Interpersonal Relations of Small Groups	R. Seaton	June 1958	Dec 1960

Sociometric measures, questionnaire responses and essays were used to assess the effects of meal preparation and planning by individuals vs. groups, on interpersonal relations and on acceptability of the items.

c. Study of Needs and Interpersonal Relations as Affected by Work and Hunger in the Arctic	R. Seaton	Jan 1960	March 1961

Test teams will break trail and haul sleds with both normal and reduced food allowances. Measures of morale and interpersonal relations will be taken during the operation. Effects of regrouping the men will also be investigated.

d. Prediction of Food Acceptance on Basis of Attitudinal and Food Composition Measures	F. Pilgrim J. Kamen	Oct 1958	Dec 1960

Preliminary evidence shows that food consumption is predicted by preference, subjective satiety and other psychological factors in conjunction with the protein, fat and carbohydrate content of the food ($R=.87$). Reduction of number of predictor variables, and extension to more foods, is underway.

e. Physico-chemical Basis of Odor Perception	H. Schutz (Contract)	Oct 1959	Sep 1960

Relate various psychological attributes of odorants to physico-chemical indices as surface tension, gas chromotographic analysis and infra red absorption. Multiple regression and factor analytic techniques are being employed.

f. Quality Control of Products by Means of Sensory Evaluations	D. Peryam	Jan 1952	Continuing

This program has continued to develop methods of measurement and to establish standards for palatability and flavor identity of procured food products.

g. Investigation of Special Scales and Procedures to Assess Acceptance of QM Materiel	B. Kroll R. Seaton	July 1959	Dec 1960

This work consists of a series of studies to determine effects of types of rating scales, of methods of presenting products and of method of asking the questions on the responses to the products or product images. The goals are increased discrimination along with greater efficiency in testing procedures.

Title	Experimenters	Date Started	Estimated Completion
h. Shaping User Acceptance	E. Smith (Contract)	July 1960	June 1961

Explore and test techniques for shaping attitudes toward new QM items of food and equipment. Techniques and procedures will be based on previously developed hypotheses concerning attitudes and attitude change, such as consonance-dissonance and "scapegoating."

i. Perception of Taste of Water	J. Kamen	Aug 1960	June 1961

Whether people learn to like or dislike the tastes of waters from different sources, and whether sensory adaptation occurs to the tastes, will be investigated. The purpose is to shed light on the process of attitude formation and change under conditions where attitude is almost solely dependent upon sensory or perceptual factors.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

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Furchtgott, E. and M. P. Friedman. Effect of hunger and satiety on odor sensitivity. Rept. Nr. 13 (Final), 31 Jul. 1959. (Contract DA-19-129-QM-844.)

Kamen, J. Variability of food acceptance behavior under normal feeding conditions. Part I. Basic results of consumption survey. QMFCIAF Rept. Nr. 30-59, Nov. 1959.

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Seaton, R. W. Response patterns to an appeal to taste irradiated foods. QMFCIAF Rept. Nr. 34-59, Jan. 1960.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

KAMEN, JOSEPH M., Dr., Research Psychologist, Research and Evaluation Section; PhD, University of Illinois, 1955. Specialization: Psychophysics of taste and odor monotony; attitude measurement; product acceptance.

PERYAM, DAVID R., Chief, Food Acceptance Branch; MS, Ohio State University, 1941. Specialization: Sensory test methods for foods; taste perception; attitudes and preferences.

PILGRIM, FRANCIS J., Dr., Chief, Research and Evaluation Section; PhD, University of Pittsburgh, 1948. Specialization: Regulation of food consumption; mechanisms of taste and odor perception; consumer preferences; psychophysics.

SEATON, RICHARD W., Research Psychologist; BA, Columbia University, 1947. (In residence, University of Chicago, Sep 1958 - date). Specialization: Social psychology, attitude change; small groups.

KROLL, BEVERLEY J., Chief, Sensory Testing Laboratory, Wilson Junior College and Illinois Institute of Technology, Chicago, 1946-1949 and 1955-1957. Specialization: Sensory test methods for foods; consumer preferences.

III. U. S. Army Quartermaster Research and Engineering Field Evaluation Agency, Fort Lee, Virginia

A. CURRENT WORK PROGRAM

1. Selection and Utilization of Test Personnel

This program was initiated due to the reduction in the number of enlisted men with college degrees available for technical and semi-technical assignments in the field test program.

Title	Experimenters	Date Started	Estimated Completion
a. Selection of Observer-Recorders for Field Testing	R. Andrews K. Ingold	Nov 1957	Continuing

Utilizing standard personnel selection techniques, it was determined that the Lowry Reasoning Test A was a better predictor of observer-recorder performance that education or any of the subtests in the general classification battery. This made possible the utilization of personnel that would have previously been rejected because of educational level. A recent cross validation of these findings has indicated that changes in the military population since the original study will require a revision of the selection process. Planning is now in progress for an investigation of criteria for the selection of test subjects for field tests under extreme environmental conditions.

2. Field Studies of Quartermaster Items

The purpose of these studies is the investigation, measurement, and control of factors affecting soldier's ratings of Quartermaster items by eliminating extraneous variables through experimental and statistical controls while providing the most valid and reliable measures of factors that are related to functional utility.

a. The Evaluation of Attitude Towards the Army as a Factor in Soldier Acceptance Ratings	R. Andrews L. Paul K. Ingold	June 1957	Continuing

Statistically significant correlations have been found between attitude towards the Army and ratings of food and clothing items. Multiple regression techniques, however, have shown that only a very small portion of the total acceptance variance is accounted for by the attitude variable.

b. Soldier Acceptance of Clothing and Equipment Items	R. Andrews L. Paul	Jan 1958	Continuing

The primary objective of this test is to identify those characteristics of clothing and equipment items that are relevant to soldier acceptance and provide valid and reliable scales

for their measurement. Factor analysis was used to identify the important dimensions of a number of characteristic items. Equal interval scales were then developed to measure some of the more important factors. Still in progress is a study to determine whether the soldier's rating of the importance of the various characteristics is related to overall acceptance.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Andrews, R. S. An investigation of the relationship between general attitude toward the Army and specific food attitudes and preference. QM R&E FEA Tech. Rept. R-1, Jun. 1958.

Jones, L. V. and T. E. Jeffrey. *Development of suitable rating scales for measuring the subjective reactions of troops using Quartermaster items under actual field test conditions.* QM R&E FEA Tech. Rept. R-5, Oct. 1959.

Paul, L. E. The construction of interval scales for measuring the acceptance of clothing and equipment in field tests. QM R&E FEA Tech. Rept. R-4, Jan. 1960.

Paul, L. E. and H. W. Hembree. The detection of guess responses in the rating of statements by the method of successive categories. Tech. Paper -- Proceedings for the Conference on the Design of Experiments in Army Research and Testing, Sep. 1959.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

ANDREWS, ROBERT S., Chief, Methods Research Branch, QM R&E FEA, Fort Lee, Virginia; MA, 1959. Psychology.

HEMBREE, HOWARD W., Scientific Director, QM R&E FEA, Fort Lee, Virginia; PhD, 1952. Human factors.

INGOLD, KENNETH R., Captain, Test Officer, Methods Research Branch, QM R&E FEA, Fort Lee, Virginia; MA, 1950. Psychology.

PAUL, LEE E., Supervisory Psychologist, Methods Research Branch, QM R&E FEA, Fort Lee, Virginia; BS, 1950. Psychometrics.

6. U. S. ARMY SIGNAL CORPS

I. U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY, FORT MONMOUTH, NEW JERSEY

A. CURRENT WORK PROGRAM

1. Internal

Studies were performed in support of the design and development of equipments and systems including the following:

Control Tower AN/TSW-1
Infrared Imaging Devices Study
Radar Set AN/TPN-8
Corps and Army Communications Systems
Unicom Subscriber Central
Subsystem Radar Set AN/MPQ-32
Detonation Location Central AN/GSS-5
Radio Set AN/GRC-50

This work was performed under Contract Nr DA 36-039 SC 78921 by Dunlap and Associates, Inc.

As part of the Laboratory Product Review Program, human factors reviews were made of the following equipments:

Radio Set AN/VRC-12 Audio Accessories
Telephone TA-341/PT
Radio Set AN/ARC-44 Power Supply
Battery Charger PP-1659
Signal Generator SG-155/U
Homing Antenna AT-784/PRC
Radio Set AN/GRC-53
Telephone Modern TA-368/TCC
Power Supply PP-2127/U
70 MM Processor and Viewer
Telephone Test Set TS-716/U

In addition, consultation was provided to research and development scientists and engineers on a wide variety of human factors considerations including the following:

Readout problems in Surveillance Radars
Body and Hand size
Maintainability
Mock ups
Operator safety
Telephone Handset Design
Telephone Ringing and Sidetone Problems

2. External

The Specification, SCL 1787, "Human Factors Engineering for Signal Corps Systems and Equipment," has been referenced in all prime equipment specifications to which it has applicability. In addition, a new "standard paragraph" has been prepared for inclusion in equipment specifications to indicate broad areas of applicable enforcement requirements.

A program for developing task-synthesis system of use to design engineers is in progress. A theoretical model and an analysis vocabulary have been developed and initial equipment and user surveys have been conducted. A catalog of equipments and an application methodology are being developed. (DA 36-039 SC 78328 - Applied Psychology Corp., 1 Jun 59--1 Jul 60).

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Dunlap and Associates, Inc.

A Guide to Human Factors Considerations in the Design of Signal Corps Enclosures. December 1959.

System Dynamics and Design Methods. October 1959.

A Methodology for Evaluation of Ground Surveillance Radars. June 1959.

Environmental Factors in Signal Corps Shelters.

Applied Psychology Corporation

First, Second, and Third Quarterly Progress Reports on Contract Nr DA 36-039 SC 78328, "Design Standards for Man-Machine Tasks in Signal Corps Systems."

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

GRIFFITH, PAUL E., Chief, Applications Engineering Branch; BA, Carleton College.

HUEBNER, DANIEL L., Chief, Human Factors Engineering Section; MA, The New School for Social Research.

BREINEN, CHARLES, SP4; BA, Psychology, University of Buffalo.

REINHARD, ALFRED G., Electronic Engineer (General).

HENNESSY, JOHN R., Psychologist; MA, New York University.

II. U. S. ARMY COMBAT SURVEILLANCE AGENCY, ARLINGTON 1, VIRGINIA (PROJECT MICHIGAN)

A. CURRENT WORK PROGRAM

All human factors research under Project MICHIGAN is done by the Engineering Psychology Group, Willow Run Laboratories, under a subproject entitled "Engineering Psychology Studies." This subproject is organized into two Objectives. During the present contract year the scientific and support manpower allocation to Objectives 1 and 2, as described below, is approximately in the radio d:2.

All work is concerned with the capabilities and limitations of human operators in the interpretation of displayed outputs of sensor subsystems of surveillance systems (photo, radar, IR) and in the processing of data from multiple sources to provide intelligence. The principal independent variables of interest are the characteristics of the displays of surveillance data (including intrinsic characteristics of sensor outputs) and of information-gathering systems for collecting and interpreting these data; the principal dependent variables are search strategies, detection times and accuracies, and decision strategies.

1. Objective 1: Investigations of advanced designs of sensor and information processing subsystems jointly with other relevant tasks of Project MICHIGAN, for the purpose of comparing alternative, feasible, and psychologically promising modes of display of sensor or multiple-source information.

a. In collaboration with the Infra-Red Laboratory, WRL, a study of the interpretation of IR strip-map records as a function of alternative frequency "clipping" techniques is underway with the best available samples of records representing different altitudes, times of day and year, weather, etc.

b. In collaboration with the Data Processing and Simulation Task of Project MICHIGAN, WRL, a study of human error in the detection and location of moving targets from Airborne MTI radar has been completed in an attempt to determine the contribution made by the human operator to the AMTI Radar subsystem output error. The report is in preparation, and further studies are planned.

c. In collaboration with the Radar Laboratory, WRL, various questions regarding the interpretation of high-resolution radar output displays are being investigated.

d. In collaboration with the Data Processing and Simulation Task of Project MICHIGAN, WRL, various processes and operator and operator-team functions associated with the collation and interpretation of multiple-source data are being examined preparatory to experimental investigations of operator and team efficiencies.

2. Objective 2: Investigations of human operator capabilities in the detection and identification of targets in heterogeneous two-dimensional (map-like) displays as a function of intrinsic characteristics of the displays, such as density and relative characteristics of pseudo-targets (visual or perceptual "noise"); number, size, shape, contrast, and patterning of targets; and certain and probabilistic relationships between target locations and prominently patterned features of the display.

a. Techniques for the production of stimulus materials which are judged to be suitable for the simulation of sensor output displays have been developed for both individual (projection equipment) and group (paper-and-pencil) studies, and proving of the technique is currently under way.

b. Studies of speed of single target detection under conditions involving variation in the density, contrast, and size will be completed during the summer of 1960. The projected displays are used in this study.

c. Studies of speed of single target detection and location under conditions involving different amounts of information with respect to the nearness of the target to prominent patterned features of the display (which vary in number and type) is underway with the printed display simulation.

d. Extension of studies with both projected and printed displays to other variables of interest in defining operator characteristics in the interpretation of two-dimensional heterogeneous displays is in the planning phase.

e. A study of the effects of instructions to the observer and background information about the display on the speed and accuracy of detection and identification has been completed using abstract verbal material for the display.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Subjective Probability in Decision Theories, by W. Edwards. UNCLASSIFIED. March 1959.

Some Effects of Target Microstructure on Visual Detection, by S. W. Smith and R. T. Louttit, Visual Search Techniques, Armed Forces--NRC Committee on Vision, Publication 712, National Academy of Sciences--National Research Council, Washington, D.C. 1960.

Tactical Aerial Photography--Photo-Interpretation Field Tests, by W. T. Pollock, CONFIDENTIAL. May 1959.

Costs and Payoffs are Instructions, by W. Edwards. UNCLASSIFIED. July 1959.

Relations Between the Engineering Psychology Group and the Simulation Task, by W. Edwards. UNCLASSIFIED. August 1959.

Engineering Psychology (1957-1959), by A. W. Melton. UNCLASSIFIED. 11 August 1959.

Psychological Measurement and a Theory of Data, by C. H. Coombs. UNCLASSIFIED. September 1959.

Presentations by A. W. Melton, W. T. Pollock, and S. W. Smith at ACSI-OCRD Meeting on "Human Factors Research in Image Interpretation, 1-2 September 1959, by A. W. Melton. UNCLASSIFIED. 4 September 1959.

Decision Making Under Risk, by C. H. Coombs and D. G. Pruitt. UNCLASSIFIED. April 1960.

The Engineering Psychology Program of Project MICHIGAN as Presented in USASRDL on 13 October 1959, by A. W. Melton. UNCLASSIFIED. 22 October 1959.

Probability Learning in 1000 Trials, by W. Edwards. UNCLASSIFIED. February 29, 1959.

Information Measures Based on Overlapping Counts for Studying Sequential Dependencies, by W. Edwards. UNCLASSIFIED. 18 March 1960.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

MELTON, A. W., Head, Engineering Psychology Group, WRL, and Professor of Psychology, University of Michigan (PhD, Yale University, $\frac{1}{2}$ time).

EDWARDS, W.D., Research Psychologist (PhD, Harvard University, 5/12 time).

FOSTER, H.F., Associate Research Psychologist (PhD, University of Michigan, Full time).

KINCAID, W.M., Mathematician, Assistant Professor of Mathematics, University of Michigan (PhD, Brown University, 1/4 time).

POLLOCK, W.T., Research Psychologist (PhD, Johns Hopkins University, Full time).

ROBINSON, G.H., Engineer (M.A., University of Michigan, Full time).

SMITH, S.W., Research Associate, Psychology (M.A., Oberlin College, Full time).

WALKER, E. L., Professor of Psychology, University of Michigan (PhD, Stanford University, 1/4 time).

III. U. S. ARMY ELECTRONIC PROVING GROUND, FORT HUACHUCA, ARIZONA,

AUTOMATIC DATA PROCESSING DEPARTMENT

A. CURRENT WORK PROGRAM

1. Systems Design

Human Factors Specialist is currently working as a member of the "design types" on the development of the Fire Support ADP Subsystem.

Human Factors areas considered are:

Analysis of tasks
Analysis of decision requirements
Formats for presenting information
Work space layout
Design of input panels
Personnel requirements
Training requirements

Methods used include detailed document analysis, preparation of decision flow charts and application of standard human engineering principles. The results consist of recommendations and reports to the Tactical System Design Division.

2. Supporting Research

a. Input Accuracy. The human operator inputting data to an ADP system is likely to be much less reliable than the electronic system. Research is planned to study the relation between human input accuracy and such factors as formats, procedures, environmental variation, and input equipment.

b. Aptitudes of Signal Corps personnel assigned to the ADP Department will be measured to determine their potential capability for maintaining ADP equipment.

3. AD HOC Studies

Empirical investigations are being made of proposed designs of special purpose input panels for the Fire Support Subsystem.

4. Systems Analysis

Studies, primarily analytical in nature, are being conducted to determine the role man should play in an ADP system and the skill and knowledge required.

5. Miscellaneous Activities

Plans were developed early in FY 60 as guides to the human factors engineering program.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Systems Design

"Fire Mission Procedures, BN FDC"

"Equipment Design and Arrangement Considerations for ADP System for Artillery"

"Development of Requirement for ADP Company Strength"

Supporting Research

"A General Model for Relating Human Factors to ADP System Performance"

"Human Input Accuracy Test -- Test Plan"

"Personnel Selection for ADP Company"

"The Application of a Logical Analysis Testing Technique to the EVATA"

AD HOC Studies

"Equipment Design and Arrangement Considerations for ADP System for Artillery"

Systems Analysis

"Methods for Decreasing Human Error in ADP Systems"

"USAEPG/ADP Department Specialized FIELDATA Troop Training Program for 1960"

"The Importance of Personnel Evaluation"

"The Evaluation of Operational Personnel in ADP Systems"

Miscellaneous Activities

"Human Factors and Training in the Field Test Facility"

"Tactical Systems Test Division Test Program"

"Human Factor Program Evaluating Man-Machine Relations in Subsystem 1a"

"Human Factors Methodology"

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

TEEPLE, J.B., Psychologist; M.A., University of Pennsylvania.

SIGNAL COMMUNICATIONS DEPARTMENT

A. CURRENT WORK PROGRAM

1. There are two current tasks involving human factor engineering in the Signal Communication Department.

a. Evaluation of Automatic Electronic Switching Equipment (Task Nr 42-58-0017).

(1) Telephone TA-341/PT
(2) Automatic Electronic Switching Central AN/TTC-12 (200-line local).
(3) Automatic Electronic Switching Central AN/TTC-13 (long distance).
(4) Automatic Electronic Switching Central AN/TTC-14 (20/40/60).
(5) Automatic Electronic Switching Central AN/TTC-15 (division tandem).

b. Pershing Communication System Equipment (Task Nr 42-0001).

Portable Scatter Communication Terminal AN/TRC-80.

EVALUATION OF AUTOMATIC ELECTRONIC SWITCHING

Human Factor Areas considered include:

(1) Intelligibility (telephone instrument)
(2) Installation and maintenance (all equipment)
(3) Signaling range (telephone instrument)
(4) Extension range (telephone instrument)
(5) Work space layout (centrals)
(6) Design of controls and displays (all equipment)
(7) Arrangement of controls and displays (centrals)
(8) Directory function (centrals)
(9) Operating and technical manuals
(10) Social environment (centrals)
(11) Analysis of tasks

PERSHING COMMUNICATION SYSTEM

Human Factor areas considered include:

(1) Operation and maintenance (all equipment)
(2) Work space layout (shelter)
(3) Design of controls and displays (all equipment)
(4) Arrangement of controls and displays (all equipment)
(5) Operating and technical manuals
(6) Social environment (shelter)

Equipment will be evaluated to determine compliance with human factors engineering design practices. As of this date only a limited amount of equipment has been received on "Evaluation of Automatic Switching" task and no equipment received on "Pershing Communication System" task.

2. Supporting Research -- None.

3. Ad Hoc Studies -- None.

4. System Analysis -- The systems approach to design will be used in an effort to improve interaction between men and the equipment so as to increase overall effectiveness of the system's mission.

5. Miscellaneous activities

Preparation:

(1) Preparing tapes of mono-syllabic words to be used in intelligibility test.

(2) Preliminary tests to determine the need for any change in plan of tests.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT -- NONE.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

ABRAHAM, J.D., Psychologist; B.A., Emory University.

COMBAT SURVEILLANCE AND AVIONICS DEPARTMENT

A. CURRENT WORK PROGRAM

1. Most of the equipments and systems undergoing operational evaluation testing by this Department originated with contractual or in-house effort sponsored by USASRDL. As Such Human Factors Engineering is considered an integral part of the initial design and developmental phase. Notable examples are the AN/USD-4 and AN/USD-5 Surveillance Drone Systems. On each of these systems, Dunlay and Associates as a sub-contractor provided a detailed Human Factors Engineering Report to the Prime Contractor.

2. Notable exceptions to this procedure are equipments or systems which originate with contractual or in-house effort sponsored by USAEPG. Here too, Human Factors Engineering is considered an integral part of the initial design and developmental phase.

3. All Test Plans originating within the Combat Surveillance and Avionics Department are reviewed to insure that specific tests are included to determine that adequate Human Factors Engineering was utilized in either the initial design and development of the equipment and any subsequent modifications to it which have been effected prior to this testing.

4. Human factor areas considered are:

Personnel requirements
Training requirements
Operation and Maintenance manuals
Check sheets
Test and/or check-out equipment
Handling equipment
Packaging
Work space layout

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Human Factors Engineering Study on the Self-Contained Automatic Navigation System (SCAN) -- 30 June 1959. MELPAR Inc.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

(None specifically assigned.)

ELECTRONIC WARFARE DEPARTMENT

A. CURRENT WORK PROGRAM

There are currently several Human Factors tasks being conducted within this department:

1. Equipment Design

a. Man-Pack VT Fuse Jammer
b. DECCA Homing Beacon Jammer
c. AN/MLQ-7 Tracking Radar
d. AN/MLQ-8 (XE-2) VT Fuze Jammer
e. Shoran-Tacan Jammer

Human Factors areas considered in these tasks include:

a. Task analysis
b. Personnel requirements
c. Training requirements
d. Operational requirements

e. Maintenance requirements
f. Work space layout
g. Systems analysis

Both analytical and empirical methods are used in evaluations of tasks. The results consist of detailed recommendations for equipment modification.

2. Internal Studies

a. Development of Indices of Maintainability of Electronic Counter-measures Equipment.

b. Human Factors Evaluation of Departmental Power Units.

3. Ad Hoc Studies (External to EWD)

a. A study to Develop an Index of Operational Complexity for Electronic Equipment.

b. A Study to Develop a Program for training Personnel to Read and Speak through Interference.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

Evaluation Report of Countermeasures Set AN/MLQ-8(XE-2).

Evaluation Report of Man-Pack EDL Type 39.

Evaluation Report of the Multi-purpose Jammer Ula-M59 Installation.

Evaluation Report of the Multi-purpose Jammer 3/4-ton Vehicle Installation.

Evaluation Report of Countermeasures Set AN/ALT-2(XN-2).

Evaluation Report of Countermeasures Set AN/QRC-23b(T).

(The above reports are CLASSIFIED, however, the titles of the reports are UNCLASSIFIED.)

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

EDWARDS, J.J., Psychologist, Head, Human Engineering Section, University of Texas.

CARRIGER, BARBARA K., Psychologist, University of Indiana.

IV. U. S. ARMY SIGNAL AIR DEFENSE ENGINEERING AGENCY, FORT GEORGE G. MEADE, MARYLAND

A. CURRENT WORK PROGRAM

1. The following list of projects are currently deriving benefits from human factors studies being undertaken principally by the University of Michigan.

a. Contract SC-70097, Martin Company, AN/FSG-1.

b. Contract SC-64627, University of Michigan, Design Study of Experiments.

c. Contract SC-64478, Hughes Aircraft, AN/MSG-4.

d. Contract SC-71183, Martin Company, AN/FSG-1, Facilities.

e. Contract SC-74882, Burroughs Corporation, Study Automatic, Target Evaluation.

2. Human Factors Areas:

a. Analysis of tasks
b. Personnel requirements (MOS studies)

c. Training requirements
d. Handling equipment
e. Pre- and In-Test Activities
f. Systems synthesis
g. Reduction of human reactions in mathematical form
h. Manual and check sheets for engineering user tests.

The methods used are basically statistical in nature. Generally, through the use of large scale computer programming, empirical results were obtained and recommendations offered.

3. Supporting Research

a. Detection and Radial Localization of Eccentric Spots of Light on a Simulated Radar Scope: This experiment represents an attempt to distinguish experimentally between localization errors which occur when the observer is asked to indicate the radial position of an eccentrically presented spot on a simulated radar scope and detection errors which occur when the observer is unable to perceive the spot. In this research, the specific items considered are:

(1) Visual Detection
(2) Visual Acuity
(3) Extent of Form Field
(4) Visual Attensity
(5) Reaction Time
(6) Binary Pattern Recognition
(7) Estimation of Number
(8) Radial Localization

b. Operator Stability: This analysis was undertaken in an attempt to find a measure of operator performance which can be used to rank operators in terms of the goodness of their performance. Stability was determined for:

(1) Time to Time
(2) Raid to Raid
(3) In relation to different functions, such elements as morale, job and training satisfaction, previous experience and performance of others.

c. Evaluation of Visual Factors in AN/FSG-1 Field Tests and Indorsement of Most Satisfactory Lighting System.

Points considered are:

(1) Light removal and room and dial illumination
(2) Smoking (Tobacco)
(3) Hedonic tone (effect of color)
(4) Visual performance with goggles
(5) Coding

4. Systems Analysis

Human Factors in the Missile Master, AN/FSG-1 Air Defense System

a. Representative man-model
b. Mathematical form of the model
c. Empirical material on operator performance
d. Future Human Factors Research
e. Design of Experiment in future field tests.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

"Progress Report on Analysis of AN/FSG-1 Operator Characteristics," by H. Foster, 15 October 1958. 2354-635-M.

"Detection and Radial Localization of Eccentric Spots of Light on a Simulated Radar Scope," by E. Rae Harcum, 25 March 1959. 2354-649-M.

"Evaluation of Visual Factors in the AN/FSG-1 Field Test," by E. Rae Harcum, 24 July 1959. 2354-655-M.

"Human Factors in the Missile Master AN/FSG-1 Air Defense System," by Foster, Kincoid, Walker, Jan 1960. 2354-25-R.

"Visual Recognition Along Various Meridians of the Visual Field IX Monocular and Binocular Recognition of Square and Circles," by E. R. Harcum, April 1959. 2144-307-T.

"Visual Recognition Along Various Meridians of the Visual Field: XII Acuity for Open and Blackened Circles Presented Eccentrically," by E. R. Harcum, April 1959. 2144-315-T.

"Visual Recognition Along Various Meridians of the Visual Field: XI Identification of the Number of Blackened Circles Presented," by E. R. Harcum and Blackwell, April 1959. 2144-314-T.

"Visual Recognition Along Various Meridians of the Visual Field: III Patterns of Blackened Circles in an Eight Circle Template," by E. R. Harcum and A. Robe, April 1959. 2144-294-T.

"Visual Recognition Along Various Meridians of the Visual Field: VIII Patterns of Solid Circles and Squares," by E. R. Harcum and A. Robe, April 1959. 2144-306-T.

"The Evaluation Program for the AN/FSG-1 Antiaircraft Defense System," Volume III, 2354-14-S, July 1959, pages 3-7.

"The Evaluation Program for the AN/FSG-1 Antiaircraft Defense System," Volume II, "The AN/FSG-1 System Field Test," 2354-9-T, December 1958, pages 6-13, 29-38.

"The Evaluation Program for the AN/FSG-1 Antiaircraft Defense System," Volume I, 2354-8-T, October 1957, pages 8-16, 36-38.

"A Technique for the Study of the Missile Master System Operation," by Harold W. Sherman, October 1959, 2354-12-R.

Symposium on Prediction of Performance of Large Scale Systems, 3, 4, 5, September 1958, held under sponsorship of USASADEA. 2354-11-S, Volume 1 paper 14 entitled "The Role of Human Factors in the Evaluation of Information Processing and Decision Making Systems," by Ward Edwards and Harriett Foster.

"Principles of Dynamic Weapon Systems Programming," by M. E. Salveson.

"Actions of Battery Commander in Target Selection During Fort Meade B Tests," by G. Schwenk, 6 April 1960.

"Tab Error Effects on Time to Lock-on and Probability of Wrong Lock-on in FSG-1," by Max S. Schoeffler, 30 March 1960.

"Experimental Analog of TAB Assignment Problem," by Max S. Schoeffler, 26 April 1960.

"Fort Meade Tests - Comments, Gusses, and Heresies," by G. Schwenk, 26 April 1960.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

(No in-house professionals.)

V. U. S. ARMY SIGNAL EQUIPMENT SUPPORT AGENCY

A. CURRENT WORK PROGRAM

1. Development and promulgation of a Maintainability Specification for Signal Communications - Electronics Equipment. Essentially classified as Maintainability Activity, this specification will establish quantitative requirements for maintainability; a program for coordination between the maintenance and design engineers; design feature guidance for achieving maintainable design; and a method for quantitatively scoring degree of achievement. It is

significant from a Human Factors viewpoint because many of the design features which are important in an ease-of-maintenance sense are equally human engineering oriented. There is a broad area of common ground between human engineering design and maintainability design. To that extent this activity contributes to progress in the Human Factors field.

2. Man-Machine Loop Data. While not formally classified as Human Factors activity, this agency makes a constant contribution in the course of coordination with the development laboratory during equipment design and in the formulation of the Maintenance Support Plan for each new equipment entering development. At the outset of planning, data are presented concerning the training, skills, and facilities available to the maintenance personnel anticipated to be responsible for maintenance of new equipment. As development progresses the maintenance requirements are closely watched in order that needs for new skills, training or additional facilities may be recognized and action initiated for implementation. In this manner every effort is made to optimize the relationship between the maintenance man and the equipment.

3. As part of the Product Review and Value Analysis Program this Agency, through its Product Review Committee's analysis of the Human Engineering Report in conjunction with the other fourteen (14) areas considered during product review, assures that vital and essential Human Factors receive proper consideration in relationship to the other disciplines bearing on the equipment design.

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE LAST CONFERENCE REPORT

ASTIA AD 219 988 Development of an Index of Maintainability: A Research Report. Munger, M. R., J. Willis, M. P., American Institute for Research, DA 36 039 SC 66488.

ASTIA AD 219 989 An Index of Maintainability: Instruction Manual. Munger, M. R., and Dannels, G., American Institute for Research, DA 36 039 SC 66488.

ASTIA AD 219 987 An Index of Maintainability: Evaluation Booklet. Munger, M. R., and Altman, J. W., American Institute for Research, DA 36 039 SC 66488.

The above publications while classed as Maintainability documents, contain a great deal of design guidance equally applicable to Human Factors design.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

(No in-house professionals.)

7. U. S. ARMY TRANSPORTATION CORPS

U. S. ARMY TRANSPORTATION RESEARCH COMMAND, FORT EUSTIS, VIRGINIA

A. CURRENT WORK PROGRAM

1. Equipment Evaluation

Title	Experimenter	Date Started	Estimated Completion
a. Lighter, Amphibious Cargo Resupply (LARC)	J.W. Bailey	Aug 1959	Sept 1961

Evaluation of the Human Factors Engineering aspects of the cab and the controls.

b. Overland Train	J.W. Bailey	Jan 1960	Sept 1961

Human Factors Engineering Study of the Overland Train, being an environmental study on the work space used, the controls, cab, the instrument panel, wind shields, steering wheel, seating foot pedal and the arrangement of the living quarters. Mock-up now ready for inspection.

2. Supporting Research

a. HFE Handbook for TC Equipment	J.W. Bailey	Jan 1960	June 1962

The preparation of a "Human Factors Engineering Handbook for Transportation Equipment Designers" has been started.

b. Effect of Vibration on Human Performance	Bostrom Research Lab	Dec 1959	Dec 1960

A contract with Bostrom Research Laboratories has been awarded through HEL, Aberdeen, Maryland, to study the effect of low frequency, high amplitude whole body vibration on human performance. The study is approximately 50% complete.

c. Aviation Crash Injury Research	F.P. McCourt TRECOM, Flight Safety Foundation	Sept 1959	Continuing

Purpose: To provide for increased crash survivability for occupants of Army aircraft. To determine the structural components most conducive to injuries to crew and passengers. To development design criteria to overcome these limitations and apply such criteria to future designs.

Status: Contract awarded in 1959 to Flight Safety Foundation of New York. The majority of work is actually accomplished by the Aviation Crash-Injury Research (AVCIR) division at Phoenix, Arizona. Contract provides for:

(1) Training courses for crash investigators (funded by O&M,A funds, monitored by this contract).

(2) Analyze and code crash injury reports for statistical analysis.

(3) Prepare general design parameters for crash safety requirements.

(4) Evaluate and report on Army model specifications and mock-ups.

(5) Formulate a manual for investigators of Army aircraft crashes.

(6) Conduct crash injury investigations of Army aircraft accidents.

Work is proceeding on each of the above items. TC is currently conducting engineering evaluations of recommendations made as a result of three Army aircraft accident investigations.

Title	Experimenter	Date Started	Estimated Completion
d. A/C Vulnerability and Pilot Armor	F.P. McCourt TRECOM Capt. J. Senna, QMC	Feb 1959	Continuing

Purpose: To determine the degree of vulnerability of Army aircraft and the optimum degree of protection which can be provided for the air crews through the combination of personnel armor and aircraft armor.

Status: At the Personnel Armor Conference in 1958, it was decided that the problems affecting the protection of aircraft and crews could best be solved on a Joint User-Inter Technical Services basis. Therefore, an Ad Hoc Committee on Aircraft Armor was organized to deal with the problems. Representatives from QM, ORD, USCONARC, MED, SIG and TC composed the membership with the TC member as chairman. A working group of this committee was formed as the Aviation Vehicle Environmental Research Team (AVERT). The team coordinator is the QM member. AVERT has published one report dealing with their analysis and recommendations for armor protection of the L-19 and its crew. AVERT is presently studying the next aircraft as published on a priority list by USCONARC.

B. BIBLIOGRAPHY OF PAPERS PUBLISHED SINCE LAST CONFERENCE REPORT

Bostrom Research Laboratories. The Effects of Low Frequency, High Amplitude Whole Body Longitudinal and Transverse Vibration on Human Performance, being the First Quarterly Progress Report for the period, 13 January 1960 - 13 April 1960. Bostrom Research Laboratories, Milwaukee, Wisconsin, April 1960. Two pages Contract No. DA-11-022-509-ORD-3300. Ordnance Project No. TEL 1000, U. S. Army Transportation Research Command. Project 9R95-20-001-010, TRECOM House Task 30002.02. MIPR Contract No. R60-8-TC-RE.

Kime, James A., and Harp, Charles H. A study of the Vulnerability of Representative Transportation Corps Installations to Biological Warfare. U. S. Army Chemical Corps, Biological Warfare Laboratories, Fort Detrick, Maryland, April 1960. 55 pages. Illustrated. U. S. Army Transportation Research Command, MIPR Contract. Fort Detrick Control No. 60-FDS-1158.

Aviation Crash Injury Research Staff. Crash Injury Investigators School, Program of Instruction. Sky Harbor Airport, Phoenix, Arizona. Aviation Crash Injury Research, Phoenix, Arizona. 10 pages. U. S. Army Transportation Research Command Contract No. DA-44-177-TC-624, March 1960.

Carroll, Jack and Knowles, William R. Draft Report of Crash Injury Evaluation, U. S. Army YHC-1B-Vertol Chinook Mock-up. Morton, Pennsylvania, January 1960. Aviation Crash Injury Research, Phoenix, Arizona, 1960. 107 pages, illustrated. U. S. Army Transportation Research Command Contract DA-44-177-TC-624.

Carroll, Jack; Knowles, William R.; Buggink, George M.; and Roegner, Harold F., Crash Injury Report, U. S. Army HU-1A, Bell Iroquois Helicopter Accident, East St. Louis, Illinois, 21 October 1959. Aviation Crash Injury Research, Phoenix, Arizona, January 1960. 49 pages, illustrated. Appendix 12 pages, U. S. Army Transportation Research Command, Contract DA-44-177-TC-624.

Carroll, Jack; Roegner, Harold F.; and Knowles, William R. Crash-Injury Report. U. S. Army U-1A DeHavilland Otter Accident, Fort Carson, Colorado, 16 June 1959. Aviation Crash Injury Research, Phoenix, Arizona. 61 pages, illustrated. U. S. Army Transportation Research Command, Contract DA-44-177-TC-624, 1960.

Roegner, Harold F. Improper Instruction in the Use of Safety Belts in the H-21 Helicopter Manual. Aviation Crash Injury Research, Phoenix, Arizona. 5 pages, illustrated. U. S. Army Transportation Research Command, Contract DA-44-177-TC-624, March 1960.

Roegner, Harold F. Draft Report of Crash Injury Ev[illegible]tion, G[illegible]man AO-1BF. U. S. Army "Mohawk" Mock-up. Bethpange, L. I., New [illegible], Mar[illegible]0. Aviation Crash Injury Research, Phoenix, Arizona, 1960. 24 pages, illustrate[illegible] . S. Army Transportation Research Command Contract DA-44-177-TC-624.

Roegner, Harold F.; Knowles, William R.; Buggink, George M., and Carroll, Jack. Crash Injury Investigation, U. S. Army H-21C, Shawnee Helicopter Accident, Big Meadows, Virginia, December 2, 1959. Aviation Crash Injury Research, Phoenix, Arizona. 57 pages, illustrated. U. S. Army Transportation Research Command. Contract DA-44-177-TC-624, February 1960. TCREC-Technical Report, 60-141.

C. BIOGRAPHICAL DIRECTORY OF PROFESSIONAL PERSONNEL

U. S. Army Transportation Research Command, Fort Eustis, Virginia

BAILEY, JOHN WENDELL, Chief, Life Sciences Division, Research Directorate, in charge of Human Factors Engineering; PhD, Harvard University, 1927.

McCOURT, FRANCIS PATRICK, Chief, Research Analysis Division, Aviation Directorate.

MERRITT, ELMER VERNON, Military Applications Branch, Research Analysis Division, Aviation Directorate.